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by

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FOREWORD

The primary mission of the Health Effects Research Laboratory is to provide data which is based on health-related research to support the regulatory activities of the Environmental Protection Agency. Research is conducted to identify, characterize, and quantitate the harmful effects of pollutants that may result from exposure to chemical, physical or biological agents found in the environment. Research data is used in the Agency's standards setting procedure to insure that man and his environment are protected.

The purpose of the investigation reported herein was to measure water quality changes that occur in open reservoirs used to store treated drinking water. At over 700 locations in this country water is treated to assure that it is safe for human consumption and then piped into the distribution system where storage is provided in an open reservoir. Water stored in this manner is subject to contamination from a number of sources and E.P.A. has recommended for years that open reservoirs should be covered.

Reservoir operational procedures practiced at Baltimore and Pittsburgh provided water to consumers which complied with the Drinking Water Standards. Results of this investigation did show a deterioration in several water quality parameters that were monitored over a one-year period, however, the changes were not severe. A preferred management plan which would improve current operational procedures and provide added protection in the delivery of a safe and potable water was recommended. The amortization of capital cost for a floating cover compared favorably with the annual cost of the preferred management plan for the 130 MG Highland Reservoir at Pittsburgh, but was not a favorable comparison for the 300 MG Druid Park Reservoir in Baltimore.

This project was initiated and funded by the Water Supply Program, Region III, Philadelphia, Pennsylvania and transferred to the Health Effects Research Laboratory where a grant was awarded and the project monitored until its conclusion.

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PREFACE

Open finished water reservoirs have long been considered to be a sanitary defect in public water supply systems. The potential health hazards associated with these so-called system "weak-links" have been recognized and acknowledged by experts in the water supply field. Moreover, the U.S. Environmental Protection Agency, as well as most states, no longer approves the construction of new uncovered finished water distribution reservoirs. The widely accepted belief is that covering reservoirs will better serve to protect public health, provide better water quality, reduce maintenance, and provide better utilization of urban resources.

A large number of water supply systems in the United States include open storage of finished waters. However, currently there has not been a detailed documentation of water quality changes experienced in operating those uncovered finished water reservoirs. This study was intended to investigate the effects of open storage of treated drinking water on quality parameters of two separate open storage reservoirs: Druid Lake and Highland Reservoir No. 1. The report provides a detailed definition of water quality and associated changes and explores possible measures including enclosure to eliminate identified water quality deterioration.

Although a comprehensive examination of water quality was undertaken for both reservoirs, including the definition of contaminants which were of concern, the examination of possible routes of entry for the site-specific contaminants, and the impacts of the contaminants on the water supply system and the users, actual water quality deterioration as defined by existing drinking water standards was not firmly established. Consequently, the approach to the final scope of the study, which involved exploring and costing possible measures to eliminate contamination and/or minimize water quality effects, was altered from what was originally envisioned at the inception of the study. The descriptions of the methods to be considered for controlling degradation of finished waters presented herein were primarily based on the risks of *potential* contamination of the respective reservoirs rather than on measured changes in water quality. Within the framework of potential contamination, a set of specific alternatives was developed for each of the storage systems under consideration and a limited trade-off assessment was performed. Basically, the alternatives for each reservoir involved various means of covering and a preferred management of the open reservoir. The preferred management alternative utilized proper, rather than existing, programs for operation, maintenance, additional treatment, monitoring, and surveillance of the respective reservoirs in question. Again, it must be emphasized that these alternatives were founded on the potential for contamination of the reservoirs as they presently exist.

The data base of this study was the water quality data collected over a 12 month period for each reservoir. This extensive documentation set the tone for the entire discussion of sources and pathways of contamination, as well as the evaluation of alternative solutions. This reservoir sampling and analysis program was restricted due to the cost and capabilities of the cooperating laboratories. Other parameters of recent interest that might have been included in this study are chloro-organics and asbestos. More efficient air pollution monitoring equipment (e.g., cyclone samplers) could also have been used during the study. Sludge or bottom sediments could have been analyzed for heavy metals. Bacterial sampling for _Salmonella_ could have been conducted on Druid Lake because of the existence of potential contamination by the waterfowl population which was present 72 percent of the time the study was conducted. The inclusion of these analyses would have effected a more comprehensive study of the problems associated with uncovered reservoirs.

Had the results of the water quality sampling program been more substantial in terms of identifying deterioration in the reservoir a more in-depth development and evaluation of alternatives could have been conducted. The following could have been considered on a case-specific basis:

1. Is there an actual need for large reservoirs under present day conditions? The reservoirs investigated herein were designed over a century ago according to the design criteria prevalent at that time. Water supply technology has significantly progressed such that large finished water storage volumes may not now be necessary. Moreover, the urban development which presently surrounds these reservoirs was not as predominant, and did not play as important a factor in their overall management. A study of present day and future water demands and the hydraulic capabilities of the specific water supply systems in question could prove to be a decisive step in the detailed evaluation of alternatives.

2. Use of a bypass scheme or other emergency plans integrated into the reservoir and available for use under emergency conditions. These schemes may require (a) micro-straining backed up by chlorination; (b) compartmentalization of the reservoir to allow periodic exchange of water with fresh water plant effluent; (c) less desirable option of "boil water order" issued when an emergency arises.

3. Covering a portion of the reservoir. This option becomes a sophisticated design problem due to monitoring constraints, wall design and other factors. In addition, the cost of the cover portion could partially offset the need for additional chlorination.

4. Utilizing air space as a revenue source. This approach initially considers the reservoir to be completely covered. After the covering of the reservoir the top or the air space above the reservoir could be utilized for an office building, civic center or other revenue producing assets.

In addition to the conclusions that were drawn concerning each particular reservoir studied in this report there are some other observations that may be made with regard to the question of open versus covered finished water reservoirs. The choice of the two reservoirs investigated in this study may well have biased the outcome as to the inordinately high costs associated with covering these reservoirs because of their relatively large sizes (130 million and 300 million gallons). A number of cities have experienced appreciable cost reductions by covering their reservoirs as opposed to operating and maintaining open finished water reservoirs. The City of Philadelphia recently covered the Oak Lane Reservoir (two basins - 35 million gallons each), and has calculated that the initial cost of floating cover installation will be offset by the potential savings in annual chemical, operational and maintenance costs required of the open reservoir for a 20 year period. Consequently, an important factor in determining whether it is cost-effective to cover a reservoir is simply size, or surface area. Had smaller-sized open finished water reservoirs been investigated in this study the conclusions derived from a trade-off assessment of covered versus open reservoir alternatives could likely have favored covering.

The salient point of the above discussion is that each specific municipal finished water reservoir situation must be studied individually in order to arrive at the best solution in terms of costs, public health and environmental quality. Each city water supply system which incorporates open storage of finished water must be evaluated on a case-specific basis so that all the costs and benefits associated with covering or maintaining an open system may be considered. Further study of this nature is required of existing open finished water reservoirs in this country before a general policy to cover all reservoirs is adopted.

In the final analysis with all costs and benefits considered, the covering of existing open storage reservoirs is expected to be the most cost-effective and sound approach in terms of public health. However, the means of covering will need to be case-specifically conceptualized and designed so as to afford additional benefits directly unrelated to public health and water supply. An example would be the construction of a civic center in the space over the covered area of a reservoir.

The fact remains that an open finished reservoir has the potential of becoming contaminated and may be considered by many health officials to be a "weak-link" in a city's water supply system. The case studies documented herein of Druid Lake and Highland Reservoir No. 1 are only the beginning of this necessary documentation.

ABSTRACT

Two open treated drinking water reservoirs were investigated with primary focus upon definition of water quality and development of alternative water quality control measures. Water quality of each reservoir was defined by a comprehensive water sampling/analysis program and water quality control measures were developed to mitigate delineated water quality problems. These control measures were evaluated on the basis of water quality improvement and preliminary cost-benefit analysis.

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CHAPTER 1

INTRODUCTION

This report investigates two open finished water reservoirs within a perspective of: (1) identifying water quality change caused by open reservoirs; (2) making a judgement of the desirability of the water quality change; (3) delineating potential causes of change in water quality; (4) developing water quality improvement measures; and (5) evaluating the water quality improvement alternatives. One of the two case-study reservoirs (Druid Lake) is located in Baltimore, Md. and the other reservoir (Highland Reservoir No. 1) is located in Pittsburgh, Pa. The following sections present the conclusions and recommendations derived in this study from evaluated water quality data and the analyses of alternative water quality control measures for each reservoir.

CONCLUSIONS

Druid Lake, Baltimore, Md.

Water Quality Evaluation

(1) The U.S. Public Health Service Drinking Water Standards of 1962 were complied with by all water quality parameters analyzed in this study.

(2) Water quality parameters of temperature, ammonia, and soluble orthophosphate did not, on occasion, meet other criteria of desirable water quality. However, these conditions did not pose any identified problems, and were of no significant concern to potability or long-term health effects of the water supply.

(3) Water quality parameters of pH, total solids, copper, and bacteria (indicated by total standard plate count) generally increased in concentration from the reservoir inlet to the reservoir outlet.

(4) Water quality parameters of turbidity, total residual chlorine, free residual chlorine, and nitrate generally decreased in concentration from the reservoir inlet to the reservoir outlet.

(5) Possible sources or causes of water quality degradation are, airborne particulates, surface runoff, groundwater, unauthorized human contact, birds, weather, and biological processes in the water.

Alternative Water Quality Control Measures

(1) Existing reservoir operations produce an acceptable, high quality effluent water.

(2) Measures to maintain this high quality water, and, more importantly, to reduce the potential of water quality degradation in Druid Lake can be classified as either preventive or corrective measures.

(3) Alternatives comprised of preventive measures such as covering the reservoir and bottom lining the reservoir, would considerably reduce the potential for introduction of contaminants.

(4) An alternative which would utilize the existing open reservoir in connection with proper operational and post-reservoir treatment procedures (i.e., corrective measures) would ensure delivery of a potable water to consumers, but the risk for potential contamination would still exist.

(5) From the standpoint of alternative costs and the associated water quality and public health benefits derived, the installation of a cover in lieu of proper operation of the open reservoir does not appear justified.

(6) The final decision as to whether Druid Lake should be covered will depend on the determination of the benefits associated with the elimination of potential water quality degradation since no absolute degradation was discovered in this study.

Highland Reservoir No. 1, Pittsburgh, Pa.

Water Quality Evaluation

(1) The U.S. Public Health Service Drinking Water Standards of 1962 were complied with by all water quality parameters analyzed.

(2) Water quality parameters of temperature and ammonia did not on occasion meet other criteria of desirable water quality. However, these conditions did not pose any identified problems and were of no significant concern to potability of the water supply.

(3) Water quality parameters of lead, phytoplankton, and bacteria (indicated by total standard plate count) generally increased in concentration from the reservoir inlet to the reservoir outlet.

(4) Water quality parameters of temperature, total residual chlorine, and free residual chlorine generally decreased in concentration from the reservoir inlet to the reservoir outlet.

(5) Possible sources or causes of water quality degradation are, airborne particulates, surface runoff, groundwater, unauthorized human contact, weather, and biological processes in the water.

Alternative Water Quality Control Measures

(1) Existing reservoir operations produce an acceptable, high quality effluent water relative to the 1962 USPHS Drinking Water Standards, although there have been occurrences of undesirable taste and odor in reservoir effluent as a result of phytoplankton growth during the summer months of July and August.

(2) Existing post-reservoir chlorination during the one-year sampling program did not appear to be contributing chlorine residual to the effluent.

(3) Measures that will alleviate these undesirable conditions, maintain the high quality of the water, and reduce the potential of water quality degradation in Highland Reservoir No. 1 can be classified as either preventive or corrective measures.

(4) Alternatives comprised of preventive measures such as covering the reservoir and bottom lining the reservoir would serve to alleviate the undesirable conditions as well as considerably reduce the potential for introduction of contamination.

(5) An alternative incorporating the present open reservoir and ensuring delivery of a potable water to consumers includes proper chemical additions for algae control, the construction of a perimeter fence to increase reservoir security, and effective post-reservoir chlorination and chlorine reaction time. However, this alternative still offers the potential risk of contamination.

(6) From the standpoint of alternative costs and the associated water quality and public health benefits derived, the installation of a floating cover on Highland Reservoir No. 1 should be considered.

(7) The final determination as to whether the reservoir should be covered should be based on a quantification of all the associated costs and benefits.

RECOMMENDATIONS

Druid Lake, Baltimore, Md.

(1) Reservoirs similar to Druid Lake (urban setting, capacity, etc.) which are covered should be investigated to determine the water quality improvements afforded by a covered reservoir. Additionally, the reduction in annual O&M costs resulting from covering these reservoirs should be determined so as to be able to extrapolate these reductions to an expected annual O&M cost for a covered Druid Lake.

(2) The costs and/or benefits should be identified for the following:

- water loss due to open storage at Druid Lake;

- potential of disease outbreak associated with deliberate or accidental contamination of the reservoir;

- prevention and/or control of potential waterfowl contamination; and

- potential of other forms of open reservoir contamination.

(3) In spite of the study reported herein an additonal, more detailed, trade-off analysis which considers all of the associated costs and benefits specific to the Druid Lake situation should be performed in order to determine whether the existing open reservoir should be used with proper management and operational procedures or whether the reservoir should be covered.

Highland Reservoir No. 1, Pittsburgh, Pa.

(1) Reservoirs similar to Highland Reservoir No. 1 (urban setting, capacity, etc). which are covered should be investigated to determine the water quality improvements afforded by a covered reservoir. Additionally, the reduction in annual O&M costs resulting from covering these reservoirs should be determined so as to be able to extrapolate these reductions to an expected annual O&M cost for a covered Highland Reservoir No. 1.

(2) All of the costs and benefits associated with both the floating reservoir cover alternative and the preferred management and operation of the open reservoir alternative (with the necessary additions and changes) should be identified including those detailed in the Recommendations for Druid Lake, as well as the value of the open reservoir to public recreation.

(3) Once the above information is assembled, a more detailed trade-off analysis should be performed in order to confirm the need to cover Highland Reservoir No.1 in lieu of upgrading existing operational procedures and installing an adequate perimeter fence.

CHAPTER II

INTRODUCTION

PERSPECTIVE

Public water supplies fulfill a vital human requirement as well as provide an essential commodity for other sectors of our modern society. Increasing demands are being placed upon water utilities to supply water in greater quantities and of higher quality to the public. Since 1950 the rate of water withdrawals by public water utilities has nearly doubled from 53 million cu m/day (14 billion gallons/day) to a withdrawal rate of 102 million cu m/day (27 billion gallons/day) in 1970 (Ref. II-1). This has caused an increase in number of water treatment facilities and more efficient use of existing facilities to maintain acceptable quality of treated water. In recent years, safe public water has become inadequate in meeting consumer acceptance of water quality on a short term basis. Water that the consumer considers "high quality" is now a necessity. The character of high quality water goes beyond the realm of human senses but exists within the public's technical knowledge of long term health. Owing to increased concern with environmental protection and the quality of our environment, citizens are becoming acutely aware of the effect of the physical, chemical, biological, and radiological effects of water quality parameters on health, economic, and to some extent, social and political aspects for our society.

The American Water Works Association has defined a functionally ideal water as follows (Ref. II-2): "Ideally, water delivered to the consumer should be clear, colorless, tasteless, and odorless. It should contain no pathogenic organisms and be free from biological forms which may be harmful to human health or aesthetically objectionable. It should not contain concentrations of chemicals which may be physiologically harmful, aesthetically objectionable, or economically damaging. The water should not be corrosive or incrusting to, or leave deposits on, water-conveying structures through which it passes, or in which it may be retained, including pipes, tanks, water heaters, and plumbing fixtures. The water should be adequately protected by natural processes, or by treatment processes, which insure consistency in quality." Such water quality may be impossible to attain but it addresses the goal of consistently producing water that is aesthetically pleasing, conducive to good health, and economically beneficial. Definitive water quality standards in terms of maintaining good health are those promulgated by the U. S. Public Health Service (USPHS) in 1962. These standards pertain to biological, chemical, physical, and radiological criteria whose minimum allowable requirements legally apply only to waters used in interstate commerce. Many states have, however, adopted these standards to apply to their own public water supplies. The USPHS standards were revised and presented for general comment in December, 1975 as the National Interim Primary Drinking Water Regulations and will become effective June 1977.

While most public water utilities can treat raw water and produce finished water which meets USPHS standards, the treated water must also reach the consumer in this high quality state. Effluent water from a treatment facility may be held in a finished water reservoir to accommodate peak flows including fire demands. The water is subsequently released as required for immediate consumption. Because many finished water reservoirs are uncovered and exposed to the ambient environment, the possibility exists for the quality of the finished water to deteriorate from the previous high quality that it possessed after treatment. New storage reservoirs are required by most states to be covered. This provides the most complete protection against possible contamination although other less expensive means of protection may be utilized to insure acceptable water quality.

Even though most new finished water reservoirs are covered, many reservoirs, some constructed during the nineteenth century, remain uncovered. A national poll of state governments was made in March 1974 (Ref. 1-3) concerning the existence of open finished water reservoirs within their municipal water systems. The major results of this poll are as follows: (1) thirty-seven of the 50 states have open finished water reservoirs; (2) approximately 750 open reservoirs exist in the United States; (3) of the 37 states indicating one or more open reservoirs, 34 require that new finished water reservoirs be covered (one of the 34 states indicated covers or post chlorination and two of the states did not respond); and (4) of the 37 states with open reservoirs 19 have a program in which existing reservoirs will be covered or replaced with covered reservoirs (of the states, two failed to respond and two indicated covers or post chlorination).

The results of this poll indicate that with 74 percent of the states possessing about 750 open finished reservoirs a significant potential water quality problem exists. Furthermore, the majority of these states recognize the possibility of contamination from the ambient environment and therefore, require that new reservoirs be covered, and have programs in which existing open reservoirs will be covered or replaced.

Open finished water reservoirs are susceptible to water quality degradation by transport of contaminants from the surrounding area. Contaminants may be: (1) air borne particulates, pesticide sprays or larger debris such as leaves which directly settle on the reservoir surface; (2) water transported solids from land surface runoff; (3) water transported solids from groundwater sources; (4) secondary contaminants from chemical reactions in the reservoir such as chlorinated compounds production enabled by the presence of chlorine in influent water or from biological growths caused by the presence of nutrients and exposure to sunlight; (5) resuspended solids from bottom sediments; (6) contaminants directly introduced by persons with unauthorized entry to the reservoir; and (7) contaminants introduced by resting birds on the reservoir surface. These problems do not generally occur in the water distribution system from the water treatment plant or point where the water is deemed acceptable to the consumer because of being protected from the ambient environment. While some problems do occur such as bacterial growths or introduction of contaminants owing to infiltration, the presence of an uncovered reservoir may be viewed as the weak link in the system.

Most water utilities with open distribution reservoirs take preventive maintenance measures to insure high water quality. This insures that consumers are not confronted with aesthetic or health problems. Typically, a water utility will respond to consumer complaints concerning water quality by developing specific remedial operation and maintenance (O&M) procedures or constructing water quality improvement aids. Even if no particular complaints are received, different O&M procedures or additional construction may be introduced to reduce existing O&M costs.

Less frequently has a water utility had to implement a major water quality improvement, such as covering, to alleviate an on-going health problem. This did occur, however, in the City of Concord, New Hampshire, when in October, 1975, the State Supreme Court ordered the city to cover their reservoir because of it being a source of bacterial and viral contamination (Ref. II-4). Other municipal water supplies may have instances of health problems where the alleged source of contamination is the uncovered finished water reservoir thus requiring additional improvement measures. An example of this situation occurred at the town of Swickley, Pennsylvania (Ref. II-5). In this case, a 62 percent attack rate of a gastrointestinal illness was estimated for the outbreak. The origin of the illness was in the municipal water system (population served = 8,000). The cause was alleged to be contamination of one of their finished water reservoirs.

Few definitive studies have been made to show that open reservoirs deteriorate specific water quality parameters. In maintaining acceptable water quality, the water utility has the option of making the open finished water reservoir part of the closed distribution system by covering it, or providing additional treatment of water in the reservoir or effluent water of the reservoir. Both measures create additional costs, and the decision of which water quality maintenance method to employ on a cost-effective basis depends upon the particular water quality problem and the availability of funds.

PURPOSE

The previous section indicated that the presence of an open finished water reservoir poses a potential threat to maintaining acceptable water quality of the municipal water supply. When a water quality problem occurs, the water utility may have difficulty in ascribing the cause to quality degradation within the open reservoir. This is principally due to a lack of water quality data and proven cause-effect relationships. The purpose of this report is to furnish water utilities via two case study analyses, with information concerning: (1) water quality change caused by open reservoirs; (2) making a judgement of the desirability of the change; (3) delineation of potential causes of change in water quality; (4) development of water quality improvement measures; and (5) evaluation of the water quality improvement measures

This case study of two reservoirs may be viewed in a general manner allowing significant extrapolation of results to similar situations. The two case study reservoirs, Druid Lake, Baltimore, Maryland and Highland Reservoir No. 1, Pittsburgh, Pennsylvania, are typical of large, open finished, water reservoirs constructed around the turn of the century, located within large industrial cities. However, the case study approach has the inherent problem of addressing specific characteristics of unique situations, i.e., two reservoirs. At a detailed level of interpretation, little extrapolation of study results is allowed owing to perceived situational differences.

SCOPE OF STUDY

Both of the reservoirs (Druid Lake and Highland Reservoir No. 1) were treated in essentially the same manner. A one year water sampling program from February, 1975 to February, 1976 was performed by the Baltimore Department of Public Works, and the Pittsburgh Department of Water for their respective reservoirs. This routine sampling program consisted of sampling two or three times per week for approximately 20 parameters, at the following points: the reservoir's influent, at the effluent before post-chlorination, and at the effluent after post-chlorination. In addition to the routine sampling program, several special water sampling programs were completed. These programs included sampling for total organic carbon, trace metals, radio-chemical phenomenon, viruses, and dust fallout plus investigations of waterfowl, benthic micro-organisms, depth profiles, and reservoir water flow.

Data analysis/interpretation dealt with the routine sampling program with emphasis upon data defining water quality at the reservoir's influent and effluent before post-chlorination. Changes in water quality between influent and effluent were determined. Results of the special sampling programs were principally utilized as background information owing to the sporadic frequency of sampling.

No specific monitoring was performed of potential external contaminant sources which might influence reservoir water quality, such as groundwater infiltration or contaminants introduced by illegal entrance. This meant that most of the developed water quality improvement measures were presented from a state-of-art viewpoint rather than being specifically directed to mitigate the influence of a particular external contaminant source. Improvement measures were evaluated by consideration of feasibility, environmental, and economic factors.

CHAPTER II

REFERENCES

II-1 *Water Policies for the Future*, Final Report to the President and to the Congress of the United States by the National Water Commission, Water Information Center Inc., Port Washington, N.Y., 1973.

II-2 *Public Water Supply Treatment Technology*, Report on Water Quality Management for Office of Water Resources Research, U. S. Department of Interior, American Water Works Association Research Foundation, 1973.

II-3 *Health Aspects of Uncovered Reservoirs*, Flutze, J.C., Water Supply and Waste Section, Washington State Department of Social and Health Services, 1974.

II-4 "Case No. 7241 City of Concord v. Water Supply and Pollution Control", The State of New Hampshire Supreme Court, October 21, 1975.

II-5 *Gastrointestinal Illness at Swickley, Pennsylvania-Evaluation of the Water Supply System*, Lippy, E.C. and J. Erb, (to be published - May, 1976, *Journal American Water Works Association*), Environmental Research Center, Health Effects Research Laboratory, Cincinnati, Ohio, April, 1976.

CHAPTER III

POTENTIAL PROBLEMS WITH OPEN STORAGE OF TREATED DRINKING WATER

INTRODUCTION

Storage of treated drinking water in open reservoirs exposes the water to possible deterioration and contamination from many sources. The extent of these effects will vary widely depending upon physical and climatic conditions. Of primary concern is the potential introduction of pathogens to the water supply which would endanger consumer health. The presence of deleterious substances which pose a long term threat to health such as heavy metals, chlorinated organics, and radionuclides is receiving increased attention. In addition to effects on health, open finished reservoirs may also cause aesthetic problems such as the presence of taste and odor within the water supply system.

The contaminant sources which may give rise to water quality problems are the following: (1) airborne particulates; (2) surface runoff; (3) groundwater movement; (4) illegal entry to reservoir; (5) resting birds; (6) aquatic organisms; and (7) exposure to ambient weather conditions.

AIRBORNE CONTAMINANTS

Particulate matter can be blown into the reservoir or can enter with rainfall. The composition of this particulate matter will be influenced by the ambient air quality. Substances from industrial sources, such as heavy metals and hydrocarbons, can enter the reservoir via this route. Organic debris blown into the reservoir is a potential source of bacterial contamination. The presence of heavy automobile traffic in the vicinity of the reservoir will result in emissions of hydrocarbons, lead, and possibly asbestos from brakes, all of which may enter the reservoir in the form of airborne fallout. Particulates which settle upon the surrounding area may subsequently wash into the reservoir if no barrier exists.

CONTAMINANTS FROM SURFACE RUNOFF

Substances deposited by man, intentionally or otherwise and exposed soils are present as erodible deposits on the surrounding area of an open reservoir. Rain or snow runoff may transport such substances to the water if no flow barriers exist. These contaminants include garbage, refuse, settled industrial smoke particulates, vehicular emissions, and ambient soils. Because of accumulating during dry periods, the first flush of runoff may be of high contaminant concentration. If this waste stream enters the open reservoir near the outlet, then an immediate contamination problem may exist.

GROUNDWATER CONTAMINANTS

While the presence of a cover on a finished water reservoir has no effect upon groundwater infiltration, most reservoirs are evaluated from a groundwater contamination viewpoint before the decision to cover is made. If the water quality problem is due solely to a groundwater source then the water supplier may elect to prevent only groundwater contamination rather than cover. Water quality problems which may develop owing to the presence of groundwater include high concentrations of nitrates, hardness constituents, and alkalinity.

CONTAMINATION BY VIOLATION OF RESERVOIR SECURITY

Open reservoirs are subject to contamination from illegal entry and vandalism. During the warmer months illegal entry for swimming is a problem, especially for large, isolated reservoirs. Objects of every description (e.g. drugs, telephone booth, human body) can be thrown into reservoirs for purposes ranging from the clandestine disposal of the object to the intentional contamination of the reservoir. If undetected, these security violations could lead to contamination of large portions of the distribution system.

CONTAMINATION BY RESTING BIRDS

The clean, calm waters in open reservoirs represent an ideal habitat for waterfowl. Both ducks and seagulls, sometimes numbering in the hundreds, have been known to frequent existing open reservoirs. The excrement from these birds is a potential source of bacterial, viral, and particulate contamination. Garbage dumps and sanitary landfills are sometimes located in the general vicinity of an open reservoir. The birds, by feeding at the dump or landfill and returning to the reservoir, conceivably can transfer pathogens to the water of the reservoir.

AQUATIC ORGANISMS

In an open reservoir, factors including sunlight, temperature, nutrients, pH, water detention, and basin depth and configuration can be conducive to the growth of algae and related plankton, midge flies and other larvae and aquatic vegetation. These growths and their decomposition products if uncontrolled can lead to taste, odor, and debris problems in the distribution system. Some algae are associated with gastrointestinal illness.

The problems of aquatic growths can be especially troublesome if the reservoir contains stagnant areas in which there is little movement of the water or only movement within a restricted area. The long residence time and warmer temperatures in these areas can lead to loss of chlorine residual which might normally restrict the aquatic growth.

EXPOSURE TO AMBIENT WEATHER CONDITIONS

Wind induced currents within a reservoir may cause water quality deterioration. Suspension of bottom sediments by such currents can increase turbidity and possibly cause taste and/or odor problems. Short-circuiting can occur, by wind induced currents, especially in large, unprotected, basins whose major axis is oriented in the direction of prevailing winds.

Deep reservoirs may stratify seasonly, possibly altering the reservoir flow-through time. More importantly, stratification may engender taste, odor, or other problems when vertical mixing is reestablished by change in wind and/or temperature.

Exposure of the reservoir to sunlight provides an energy source for growth of phytoplankton and also acts to reduce the concentration of residual chlorine within the reservoir. The presence of phytoplankton allows the existence of other aquatic organisms which feed on them and may in themselves increase turbidity and create taste and/or odor problems as discussed in the section concerning aquatic growths. The presence of sunlight and/or the associated heat will reduce free available chlorine possibly resulting in the production of chlorinated compounds which may be harmful to the health of consumers. Furthermore, the lack of a cover allows vaporized chlorine to escape to the atmosphere thus requiring higher initial concentrations of chlorine to maintain an adequate residual from influent to effluent.

CHAPTER IV

DRUID LAKE, BALTIMORE: A CASE STUDY

INTRODUCTION

Druid Lake was selected as a case study because it is typical of old, large, uncovered reservoirs located in an intensely developed, industrial city. The study of Druid Lake would benefit the City of Baltimore because the city was considering the emplacement of a cover on the reservoir. However, owing to the size and depth of the reservoir, covering would be very expensive (Ref. IV-1). Additionally, because Druid Lake is located in a park, a cover would be aesthetically objectionable. Baltimore is considering a cover primarily in response to a survey conducted by the U.S. Environmental Protection Agency of the Baltimore water supply system, March 6-10, 1972 (Ref. IV-2) which recommended covering Druid Lake plus six other reservoirs within the water system. While consumers of water from Druid Lake have experienced an occurrence of taste and odor owing to an unusual presence of biological growths, the recommendation to cover by EPA was based more upon potential problems than existing problems.

In the interests of performing the study, a practical reason for selecting Druid Lake was that the Water Treatment Section of the Division of Water, Baltimore Department of Public Works was willing to provide both personnel and equipment for a water sampling and analysis program. Furthermore, information concerning water flows, water quality monitoring, and general operation and maintenance was also provided.

PHYSICAL CHARACTERIZATION OF DRUID LAKE

Physical Attributes

Druid Lake is located in northwest Baltimore in close proximity to the downtown area. The reservoir is an integral part of Druid Hill Park, a large public park containing a zoo, swimming pools, and other recreational facilities. Druid Lake is a part of the Baltimore water distribution system which includes seven open reservoirs with a total storage capacity of 2.27 million cu.m. (600 million gallons).

The lake, constructed in the late 1800's, has an earthen bottom and covers about 20 ha. (50 acres). The reservoir has a total normal volume of approximately 1.2 million cu.m. (300 million gallons) and an average depth of about 6 m. (20 feet). Treated water flows by gravity to the lake from an open reservoir at the Montebello Filter Plant No. 2 and enters Druid Lake through a diffuser pipe in the west end. The average flow into the lake during 1975 was 112 million cu.m./day (42.7 million gallons per day), resulting in a theoretical residence time of 7.2 days. Water leaves the lake through a discharge manifold in the east end of the lake.

The reservoir is surrounded by a fence bearing "No Trespassing - Filtered Water" signs. This fence is about 1.8 m. (6 feet) high and set back from the water about 15.2 m. (50 feet). The fence is built on a parapet wall about 0.6 m. (2 feet) high, eliminating most of the surface drainage into the lake. A roadway used by both automobiles and pedestrians circumscribes the reservoir outside the fence.

Numerous ducks and seagulls frequent the lake throughout the year. No attempts have been made to prevent their use of the basin. In the shallow portions of the lake, there is scattered plant growth, principally aquatic grass.

Existing Water Quality Monitoring Program

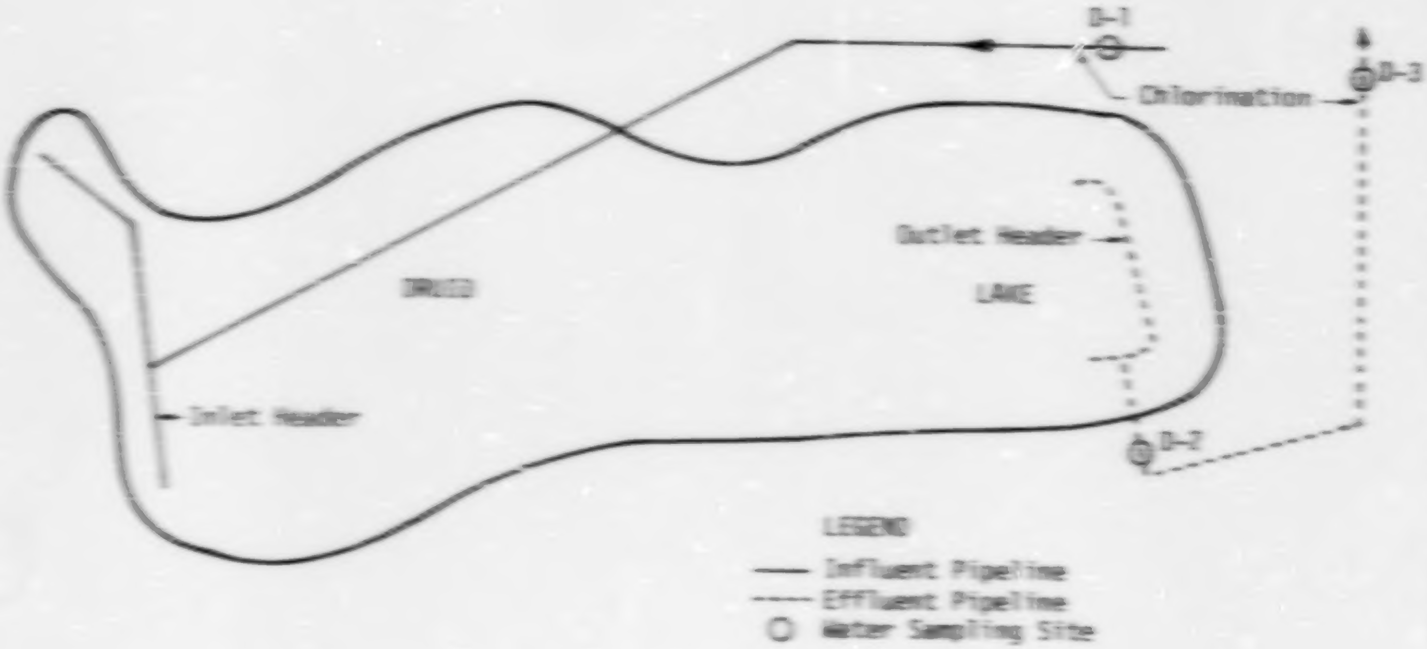
Routine monitoring of water quality in Druid Lake consists of taking grab samples from the east and west ends of the reservoir (Figure IV-1) once each week. These samples are analyzed for total coliform bacteria, micro-organisms, pH, turbidity, color, and temperature. If the presence of total coliform bacteria is detected, then the reservoir is immediately tested for the presence of fecal coliform bacteria. Typically, a 24 hour lag exists between water sampling and bacteria analytical results. Residual chlorine is monitored 6 days per week. The quality of influent water to Druid Lake is determined by monitoring the influent to the holding reservoir, which follows the Montebello water treatment plant, for, at minimum, the parameters necessary to meet 1962 U.S. Public Health Service Standards. Additional water quality sampling and analysis is performed after post-chlorination of Druid Lake effluent. The parameters monitored at this point are total coliform bacteria, temperature, residual chlorine, pH, fluoride, and micro-organisms.

Operation and Maintenance

Operation and maintenance procedures at Druid Lake are implemented to insure continuous high water quality of effluent water and throughout the reservoir. Quality of water delivered to consumers must meet USPHS, 1962, water quality standards. Water to Druid Lake from the Montebello water treatment plant has undergone prechlorination, chemical coagulation, sedimentation, filtration, fluoridation, and possible postchlorination (Ref. IV-3). Chlorination after filtration/fluoridation is designed to maintain a residual chlorine concentration of 1.0 ppm at the influent to the holding tank. The residual concentrations at the effluent end of the holding tank are typically between 0.1 - 0.2 ppm.

Holding tank effluent with the above residual chlorine concentrations then flows to the influent diffuser at the west end of Druid Lake (Figure IV-1). Before reaching the diffuser, additional chlorine is added (pre-reservoir chlorination) on a basis designed to provide a chlorine

FIGURE IV-1 LOCATION OF WATER SAMPLING SITES FOR DRUID LAKE


D-1
Chlorination
D-3
Outlet Header
DRUID
LAKE
Inlet Header
D-2
LEGEND
— Influent Pipeline
---- Effluent Pipeline
○ Water Sampling Site

Note: Site Location Numbers are Referred in Text

Scale: 1"=410 ft.

concentration of 3 - 5 ppm during summer and 1 - 3 ppm during winter. Effluent water from Druid Lake leaves through a multiple outlet structure, receives additional chlorine and then enters the distribution system by gravity flow or pumping. Post-reservoir chlorination insures that 1 - 2 ppm chlorine residual is maintained in effluent water. The in-line contact time in the distribution system is unknown.

Both prechlorination and postchlorination required a total of 113,000 kilograms (250 tons) during 1975 at a cost of $0.23/kg ($210/ton), January to June, and $0.28/kg ($250/ton), June to December, for a total cost of $58,300 per year (1975).

Operational maintenance of the reservoir itself is simple and direct. In order to control growth of algae, copper sulfate is applied by hand from a row boat to the water's surface or by dragging burlap bags filled with $CuSO_4$ behind the boat, particularly near the shore line. During 1975, six applications of copper sulfate were made of 544 kg (1200 lb) each on 9 April, 19 May, 20 June, 21 July, 12 August, and 15 October. The cost of copper sulfate alone was a total of $2,520/year at $0.77/kg ($700/ton).

Control of weeds growing among the rock rip-rap along the banks of Druid Lake is accomplished by two deweeding operations per year during summer-fall as needed. For each operation, deweeding entails two crews of six men each working for one week (8 hr/day, 5 day/wk) at a cost of $2,100, or a total cost of $4,200 per year (1975).

Surveillance of Druid Lake in maintaining security is accomplished by routine periodic checks by police who patrol the perimeter in vehicles. This arrangement is convenient to the police because, regardless of Druid Lake, they must patrol the park in which the reservoir is situated. In addition to police surveillance, employees of the Water Department provide security six days per week as they go to and from the chlorination station, and on a sporadic basis (other Department employees during daily travel and investigations).

Water Quality Problems

Historically, the public water supply of Baltimore has provided a very high quality water to its consumers (Ref. IV-2). There has only been a single occurrence of unpleasant taste and odors in the water from Druid Lake. The cause of such taste and odors was generally associated with the presence of biological growths. Apparently, a blue-green algae bloom occurred in the raw water reservoir which precedes the water treatment plant. The cellular decomposition products of the algae were not removed at the treatment plant and were subsequently passed on to Druid Lake. This resulted in an "earthiness, or swampiness" characteristic in the water which was offered to consumers.

Another source of water supply system problems that is now under control has been traced to an aquatic grass, *Vallisneria americana*, which is found growing in the fringe areas of Druid Lake. This species of plant becomes troublesome in the late summer when dead pieces of the plant become free-floating and enter the distribution system. Solids in the water supply tended to cause laundry water strainers to become clogged.

Growth of the grass has been controlled by the application of copper sulfate directly to the areas of plant growth when the reservoir was lowered to a level below these areas.

An example of a particular water quality problem is one which developed in the summer of 1966, caused by a massive algae growth (*Chlorella*) in Druid Lake. Counts of *Chlorella* between two and five thousand organisms per milliter were recorded. Treatment of the reservoir with 35,400 kg (78,000 pounds) of chlorine and 820 kg (1800 pounds) of copper sulfate did not control the bloom. A routine check of nutrients in the lake indicated phosphate concentrations of 0.1 to 0.2 mg/l as PO_4. This was unexpected since the raw water usually contained around five parts per billion phosphate. The source of phosphate was traced to hydrofluosilicic acid added during fluoridation. This acid had been obtained from a new supplier and was found to contain from two to six percent phosphate. The use of the high-phosphate acid was discontinued and the counts of *Chlorella* fell from 4000 per ml to 100 per ml in two weeks.

WATER QUALITY SAMPLING PROGRAM

Perspective of Sampling Program

Three programs were established to collect baseline characterization information of Druid Lake. The programs are: (1) routine sampling; (2) special sampling; and (3) characterization studies. The purpose of the routine sampling program was to provide information with which to compare influent and effluent water quality. This comparison determined if water quality is altered in Druid Lake and if the alteration is significant. Biological parameters are monitored before and after reservoir post chlorination in order to determine the disinfection effect of chlorination upon reservoir effluent. The routine sampling program for 21 physical, chemical, and biological parameters is supported by much less intensive sampling in the special sampling program. This program monitors change of parameters specifically identified as health detriments, e.g., radiochemical isotopes but which are not likely to occur as health problems in municipal water supplies.

Characterization studies provide background information and spot checks upon conditions which indirectly affect or reflect water quality of the reservoir, such as monitoring dustfall and identifying resident benthic organisms.

Routine Sampling Program

Water Quality Parameters

The routine sampling program required water sampling and analysis by the Baltimore Water Department for physical, chemical, and biological parameters necessary to evaluate water quality within a context of meeting health and aesthetic criteria. The analysed water quality parameters and analytical techniques are shown in Table IV-1. Laboratory analysis is

TABLE IV-1

WATER QUALITY PARAMETERS AND ANALYTICAL TECHNIQUES USED IN STUDY OF DRUID LAKE

Parameter	Analytical Technique (Ref. IV-5)
Chemical-Physical	
Temperature	Mercury Filled Thermometer
pH	Glass Electrode Method
Color, Apparent	Platinium-Cobalt Standard
Turbidity	Nephelometric Method
Total Solids	Dissolved Solids plus Suspended Solids
Dissolved Solids	Specific Conductance
Suspended Solids	Filterable Residue
Alkalinity, Total	Standard Acid Titration
Hardness, Total	EDTA Titrimetric Method
Chlorine, Total Residual	Orthotolidine Method
Chlorine, Free Residual	Orthotolidine Method (OTA Modification)
Copper	Atomic Absorption, Spectrophotometric
Lead	Atomic Absorption, Spectrophotometric
Ammonia	Nesslerization Method
Nitrate	Brucine Method
Phosphate, Total	Stannous Chloride Method
Phosphate, Ortho, Soluble	Stannous Chloride Method
Biological	
Coliforms, Total	Total Coliform MPN Test; Membrane Filter Test
Coliforms, Fecal	Fecal Coliform MPN Test
Plate Count, Total Standard	Standard Plate Count
Phytoplankton	Sedgwick-Rafter Procedure

performed according to the procedures in "Standard Methods" (Ref. IV-5).

Sampling Sites and Time Period

Water samples are collected by the Water Department at the following locations (shown in Figure IV-1 as D-1, D-2, and D-3).

(D-1) Influent water after pre-reservoir chlorination,
(D-2) Effluent water before post-reservoir chlorination, and
(D-3) Effluent water after post-reservoir chlorination.

All parameters listed in Table IV-1 are sampled from locations D-1 and D-2. Only biological parameters are sampled at location D-3.

The sampling and analysis program began 1 February 1975, and ended on 31 January 1976. From 1 February 1975 to 30 April 1975, samples were collected from each sample site twice each week. Since the most significant water quality changes were expected to occur during the summer months, samples were collected from each location three times per week from 1 May 1975 to 31 October 1975. During the remainder of the study period, from 1 November to 31 January 1976, samples were collected at each location, twice each week.

As a check on existing conditions at the time of sampling, an "environmental check list" was completed at the time of sampling for each sample date. The list included a estimation of: (1) air temperature; (2) presence andtype of precipitation; (3) wind velocity; (4) presence of clouds; (5) numbers of birds on lake surface; (6) presence of waves; and (7) unusual activities on or around Druid Lake.

Special Sampling Program

In parallel with the routine sampling program (February, 1975-January, 1976), samples were collected for special analyses by EPA laboratories. The parameters, frequency of measurement, and laboratory performing the analysis are listed in Table IV-2. Except for the microbe sampling, water samples were collected by the Baltimore Water Department and forwarded to the appropriate EPA laboratory. Microbe sampling was performed by EPA personnel. Sampling stations were located at the same influent and effluent-before post chlorination stations, D-1 and D-2, (Figure IV-2) as in the routine sampling program.

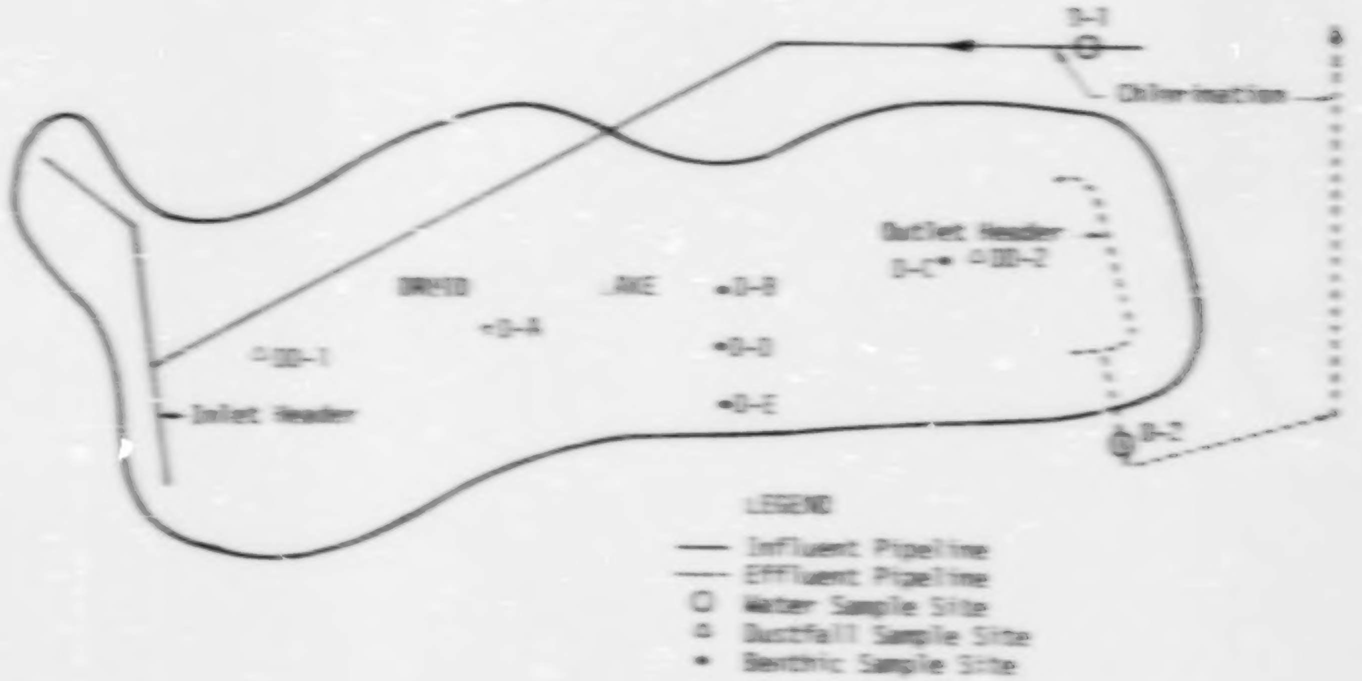
Analytical techniques for total organic carbon, trace metals, and radiochemical isotopes follow the procedures found in Standard Methods (Ref. IV-5). A modified form of the microporous filter technique originally described by Metcalf (Ref. IV-6) was used for analysis of cytopathic viruses. Analysis for coliform bacteria was performed using a modified MPN procedure (Ref. IV-7).

TABLE IV-2

SPECIAL WATER QUALITY ANALYSES-
DRUID LAKE

Parameter	Frequency	EPA Laboratory
Total Organic Carbon	Weekly	Annapolis, Md.
Trace Metals	Monthly	Cincinnati, Ohio
Barium		
Chromium		
Copper		
Manganese		
Lead		
Iron		
Cadmium		
Zinc		
Radiochemical Isotopes	Quarter Yearly	Birmingham, Ala.
Gross Beta		
Gross Alpha		
Sr-90		
Ra-226		
Specific gamma		
Microbes	Quarter Yearly	Cincinnati, Ohio
Cytopathic Viruses		
Coliform bacteria		

FIGURE IV-2 LOCATION OF WATER SAMPLING SITES FOR DRUID LAKE SPECIAL WATER SAMPLING PROGRAM


D-1
Chlorination
Outlet Header
D-C
DD-2
DRUID LAKE
D-A
D-B
D-D
D-E
DD-1
Inlet Header
D-2
LEGEND
Influent Pipeline
Effluent Pipeline
Water Sample Site
Dustfall Sample Site
Benthic Sample Site

Note: Site Location Labels are Referred in Text

Scale: 1"=400 ft.

Characterization Studies

Water Quality and Benthos Survey

During late summer, when reservoir stratification was most likely to occur, a survey of water temperature and dissolved oxygen (DO) at various depths was performed to observe any existing stratification. The survey was conducted by Engineering-Science, Inc., McLean, Virginia with aid from the Baltimore Water Department. Measurements were made directly using a portable temperature and DO meter, and probe. Water was sampled at 1.5 m (5 ft.) intervals from surface to bottom at three locations (Figure IV-2), D-A, D-B, and D-C. These locations are at the deeper areas of the reservoir.

A qualitative survey of benthic organisms was made at the same three sites as temperature and DO plus two additional sites (D-D and D-E) making a transect toward shore from the center site, D-B (Figure IV-2). Bottom sediment samples were collected using an Eckman dredge. Samples were preserved in 10 percent formalin solution. Microorganisms were identified by the Water Department of Pittsburgh, Pennsylvania using the Sedgewick-Rafter method (Ref. IV-5) (Samples were sent to Pittsburgh).

Dustfall Sampling

The amount of airborne particulates settling upon Druid Lake was measured from April, 1975 to January, 1976. Two floating dustfall samplers were anchored in Druid Lake (Figure IV-2), one at each end. Sample collection was performed by the Baltimore Water Department on a monthly basis, and sample analyses was performed by the Baltimore Department of Air Pollution.

Potential Contamination by Birds

Chesapeake Bay provides an excellent habitat for birds such as seagulls and waterfowl. While seagulls are continual inhabitants, waterfowl are found in greatest abundance during the winter due to seasonal migration. Owing to the close proximity of Druid Lake to the Chesapeake Bay (approximately 4.8 Km (3 miles) to the nearest tributary) a need existed to explore the potential of contamination by resting birds on Druid Lake. The Baltimore Water Department, as part of the aforementioned "environmental check list" that was completed on each sampling date, noted the numbers of birds on the lake surface for this purpose. Because seagulls may carry pathogenic organisms such as fecal streptococci and salmonella after foraging in local garbage dumps or sanitary landfills, several of these facilities were also surveyed for the presence of seagulls. In addition, the proximity of all such facilities to Druid Lake was determined.

Hydraulics of Druid Lake

A computation of average water detention time in Druid Lake and flow through the reservoir, was made for the time period March, 1975-January, 1976. Existing information concerning reservoir volume was obtained. At monthly intervals, daily influent flow to Druid Lake was provided by the Water Department along with reservoir water elevations. Using a volume/elevation chart, the daily change in volume of water was determined. Change in water volume per time was used to adjust the influent flow resulting in a computed effluent flow from the reservoir.

Residence time was calculated using the annual average daily flow and the average reservoir volume.

EVALUATION OF WATER QUALITY DATA

Principles of Evaluation

Data were collected to characterize water quality of Druid Lake and circumstances affecting water quality. In this study, the absence of a cover on the reservoir was deemed as an omnipresent factor which potentially changes the high water quality of influent water. Most of the data were collected and evaluated to observe any change in quality between influent and effluent water. The remainder of the data were collected to evaluate the effectiveness of postchlorination.

While the most important principle of evaluation was to observe any relative water quality change from influent to effluent and effluent before and after postchlorination, water quality data were also evaluated with respect to water quality standards. The standards used were those of the U. S. Public Health Service (1962). The forthcoming Federal water quality standards presently published as the National Interim Primary Drinking Water Regulations (Ref. IV-8), were strictly adhered to in this study because the final regulations will not be adopted until spring of 1977.

Data Presentation and Evaluation of Routine Sampling Program

Results of the routine sampling program (Table IV-1) are presented in several levels of detail. A detailed listing of analytical results for all parameters at all sampling stations is located in the Appendix of this report (Table A-1). Information is shown by sample collection, date, parameter, sampling site, and lower limit of analytical detection for the particular parameter. Data are presented for different sample dates in Table A-1 to account for reservoir detention time lag. This facilitates comparison of water quality between influent and effluent. The time lag between sample sites, before and after postchlorination is insignificant. The time lag between influent and effluent data approximates the theoretical detention time of 7.2 days. Between February, 1975 to May, 1975 the lag in Table A-1 is 7 days; May, 1975 to November, 1975 - 5 days; and November, 1975 to January, 1976 - 7 days.

Routine sampling results in Table A-1 are summarized by presenting the monthly median and range for almost every parameter in tabular fashion. For each parameter, the range and median are given for each sample site. The parameters of ammonia and apparent color were not treated in this manner owing to their uniform values of measurement.

Of the parameters selected to present as monthly medians and ranges, four parameters were chosen as warranting additional analysis. This additional analysis is designed to evaluate the difference in parameter values between sample sites. To indicate the change in water quality visually, monthly median difference plots are presented. In order to evaluate the significance of the difference in water quality, a statistical analysis, Mann-Whitney 'U' Test (Ref. IV-9), was performed with data of the four parameters. Because some of the data are not normally distributed, the Mann-Whitney 'U' Test was selected as one of the most powerful non-parametric tests. The 'U' test will indicate the similarity of two independent groups of data drawn from the same population, and as such, is an alternative to the more commonly used parametric Students 't' Test. Specifically, data from the two sample sites to be compared were drawn from Table A-1 of one parameter for a given month. The values are ranked from lowest to highest and the following equation is used to compute the 'U' statistic:

$$U = n_1 n_2 + \frac{n_1 (n_1 + 1)}{2} - R_1$$

where:

n_1 = the number of values in the smaller of the sample site groups;

n_2 = the number of values in the larger; and

R_1 = the sum of the ranks assigned to the group whose sample size is n_1.

Significance tests of difference between the two groups are made using the computed 'U' statistic, U_0. The test criteria is "two-tailed" because the test is for a difference regardless of direction, i.e., higher or lower values. The null hypothesis, H_0, states that water quality is the same at two different sample stations. The alternative hypothesis, H_a, states that water quality at the two sample stations is different.

Hypothesis H_0 is tested within four ranges of significance levels (α):

(a) $\alpha \leq 0.01$;

(b) $0.01 < \alpha \leq 0.05$

(c) $0.05 < \alpha < 0.10$; and

(d) $\alpha \geq 0.10$.

The critical region for rejecting H_0 exists when $U_0 < U_\alpha$; where U_α is determined by using tables (Ref. IV-9) listing critical values of "U" for a selected "α". When $U_0 > U_\alpha$, H_0 can be rejected at a confidence level of [(1 − α) 100] %. In a few cases, where $n_2 < 9$ (i.e., fewer than 9 sample dates during a month), a different set of critical value tables were used, resulting in direct determination of an "α". This "α" falls within one of the four ranges of significance levels from which a confidence probability or range of confidence probabilities can be calculated. For each parameter analyzed, the confidence probability of dissimilar water quality between sample sites is presented in tabular fashion by month. In addition, the range of significance levels (α) along with both U_0 and U_α are given. Where "α" was directly determined, this value is given in lieu of U_0 and U_α.

Results of Data Evaluation

Routine Sampling Program

Temperature - On a seasonal basis, the temperature of both influent and effluent water follows ambient temperature changes with warmer water in summer and cooler water in winter. This trend is indicated by the monthly medians of both sample stations shown in Table IV-3.

The impact of exposure to sunlight and changing air temperature is reflected by the effluent medians being lower than influent medians during winter and higher during summer.

Tap water with a temperature of 10°C (50°F) is generally satisfactory while temperatures above 15°C (59°F) are usually objectionable with possible consumer complaints above 19°C (66°F) (Ref. IV-10). When these criteria are applied to Druid Lake influent median temperatures equal or exceed 15°C for six months while effluent median values exceed 15°C for five months. However, the effluent medians greater than 15°C are about 1.1°C (2°F) higher than influent values. Thus, exposure of the reservoir to sunlight and ambient temperatures leads to a less aesthetic pleasing water during summer. This less aesthetic water condition is shorter in duration during autumn owing to cooler temperatures.

pH - The yearly pattern (i.e., temporal increases and decreases) of effluent pH values closely follows that of the influent. The effluent has higher median values (Table IV-3). The reservoir has a buffering effect, with an effluent, yearly, median change of 0.2 units while influent pH changes 1.1 units.

Values of pH generally increase slightly from influent to effluent, usually 0.2 units. However, during fall and early winter, pH increases by approximately 0.5 units.

The USPHS standards of 1962 set no limits on pH, however, effluent values of pH in Druid Lake are within an acceptable range.

Color, apparent - Measurements of color vary little either yearly during the sampling period or spatially (see Appendix, Table A-1). An

TABLE IV-3

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
DRUID LAKE - TEMPERATURE AND pH

Month 02/75–01/76	Temperature (°F)[1]				pH (units)[2]			
	Influent		Effluent-No Chlorination		Influent		Effluent-No Chlorination	
	Range	Median	Range	Median	Range	Median	Range	Median
February	38–44	39	39–42	39	7.2–7.6	7.3	7.2–7.6	7.4
March	40–45	41	40–43	41	7.3–7.6	7.4	7.3–7.6	7.4
April	42–47	44	43–53	45	6.9–7.6	7.4	7.2–7.7	7.4
May	45–60	54	50–65	58	6.9–7.5	7.1	7.0–7.5	7.2
June	58–69	62	62–70	66	7.0–7.8	7.2	7.2–7.8	7.5
July	66–71	68	70–74	72	6.9–8.0	7.5	7.3–7.9	7.6
August	62–75	70	65–75	73	7.2–7.9	7.5	7.3–8.3	7.6
September	60–72	62	63–67	64	6.3–7.7	7.1	7.2–7.9	7.3
October	61–66	62	61–66	63	6.0–6.8	6.4	7.0–7.5	7.2
November	55–61	59	54–60	56	6.5–7.1	6.8	7.2–7.7	7.3
December	42–50	48	41–52	45	6.6–7.1	6.9	7.0–7.7	7.3
January	36–48	41	36–40	38	6.3–7.5	6.9	7.2–7.6	7.4

Note: (1) 32°F = lower limit of detection for temperature (one Centigrade deg. = 1.8 Fahrenheit deg.)

(2) 0.01 unit = lower limit for detection of pH.

isolated, slight increase of color in influent water (from ≤1.0 unit to 7.0 units) is noted during the last week of September. The higher level of color is eliminated during residence in the reservoir to a level less than or equal to 1.0 unit. This increase of apparent color in the influent is supported by higher values of turbidity, suspended solids, and to a lesser extent, dissolved solids and total solids (Appendix, Table A-1).

All color measurements are less than the USPHS standard (1962) of 15 units.

Turbidity - Little yearly variation of turbidity exists in Druid Lake, as indicated by monthly median values in Table IV-4. The maximum difference between influent medians is 0.27 FTU and between effluent medians, 0.17 FTU. Effluent measurements follow the same trend as influent with generally higher values in early spring (February and March) and early fall (September and October).

Turbidity decreases from influent to effluent during most of the year with the exception of fall when a slight increase is observed from October through December.

All turbidity measurements are much less than the USPHS standard of 5 FTU.

Total solids - Effluent concentrations of total solids follow, for the most part, the same yearly trends as influent values (see median values in Table IV-5). Generally higher values occur during June, August, and September.

The difference between influent and effluent concentrations is typically small, usually about a 6 mg/l increase in effluent. During the months of February, March, and July, the reservoir experiences a decrease in total solids from influent to effluent.

The USPHS standards do not limit total solids. However, the USPHS does set a limit on a component of total solids, dissolved solids, of 500 mg/l which is much higher than the usual value of about 115 mg/l total solids found in Druid Lake.

Dissolved solids - Concentrations of dissolved solids, as shown by monthly median values in Table IV-5, are the same as those of total solids, except effluent medians from April through June. This indicates that most components of total solids are contributed by dissolved solids. The effluent values from April through June differ by 5 to 19 mg/l and are probably insignificant.

All concentrations of dissolved solids meet the USPHS Water Quality recommended standard of 500 mg/l.

TABLE II-4

MONTHLY MEDIANS AND RANGE OF ROUTINE WATER SAMPLING DATA
DRUID LAKE - TURBIDITY AND TOTAL CHLORINE

Month 02/75–01/76	Turbidity (FTU)[1]				Total Chlorine (mg/l)[2]			
	Influent		Effluent-No Chlorination		Influent		Effluent-No Chlorination	
	Range	Median	Range	Median	Range	Median	Range	Median
February	0.30–0.87	0.40	0.20–0.41	0.30	1.20–1.60	1.40	0.15–0.30	0.25
March	0.32–0.67	0.41	0.18–0.54	0.32	0.65–7.60	1.50	0.01–0.35	0.05
April	0.23–0.61	0.31	0.22–0.44	0.28	1.00–4.50	2.10	0.01–0.01	0.01
May	0.14–0.43	0.18	0.16–0.29	0.24	1.70–6.00	3.75	0.01–0.10	0.05
June	0.16–0.61	0.27	0.17–0.36	0.24	0.90–5.20	3.30	0.01–0.35	0.10
July	0.17–0.80	0.30	0.20–0.60	0.26	0.05–5.60	4.00	0.07–0.25	0.10
August	0.21–0.70	0.27	0.16–0.28	0.21	0.15–5.25	3.50	0.01–0.90	0.20
September	0.16–1.60	0.32	0.16–0.57	0.27	1.00–5.00	3.25	0.01–0.70	0.15
October	0.15–5.30	0.31	0.12–0.50	0.37	1.80–6.00	4.50	0.01–0.20	0.05
November	0.11–0.27	0.16	0.18–0.26	0.24	4.00–5.50	4.30	0.01–0.25	0.01
December	0.12–0.60	0.14	0.14–0.50	0.20	4.00–8.00	5.00	0.01–0.10	0.01
January	0.14–0.75	0.25	0.11–0.35	0.24	5.40–6.00	5.40	-	-

Note: (1) 0.05 FTU = lower limit of detection for turbidity.

(2) 0.01 mg/l = lower limit of detection for total chlorine.

TABLE II-5

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
[illegible] LAKE - TOTAL SOLIDS AND DISSOLVED SOLIDS

Month 02/75-01/76	Total Solids (mg/l)(1)				Dissolved Solids (mg/l)(2)			
	Influent		Effluent-No Chlorination		Influent		Effluent-No Chlorination	
	Range	Median	Range	Median	Range	Median	Range	Median
February	116-126	123	81-124	117	115-125	123	81-124	117
March	70-120	101	51-113	94	70-120	101	51-113	94
April	81-148	104	42-148	130	81-148	104	42-148	114
May	98-125	112	97-130	116	98-125	112	97-130	125
June	105-138	131	87-145	135	105-138	131	87-145	136
July	90-130	103	93-124	96	88-129	103	93-124	96
August	112-141	125	117-138	131	112-141	126	117-138	131
September	86-138	121	79-138	122	86-138	121	82-138	122
October	91-136	107	94-127	129	91-134	107	94-127	109
November	105-122	111	108-136	113	105-116	111	108-136	113
December	103-135	107	95-114	110	103-135	107	95-114	110
January	91-120	106	89-116	107	91-110	106	87-116	107

Note: (1) 1 mg/l = lower limit of detection for total solids.

(2) 1 mg/l = lower limit of detective for dissolved solids.

Suspended solids - Yearly concentrations of suspended solids show a slight trend of higher values during late summer and early fall (see monthly medians in Table IV-6). Very little difference exists between influent and effluent values.

No limit upon suspended solids has been set by the USPHS. A typical maximum concentration for domestic water supplies is approximately 5 mg/l (Ref. IV-11) which is greater than any value in Table IV-6.

Total alkalinity - Monthly median concentrations shown in Table IV-7, indicate slightly higher values during late winter (February and March) and summer (August and September) for both influent and effluent.

Alkalinity concentrations vary little between influent and effluent with a typical difference of about 1 mg/l.

The USPHS has set no limit for alkalinity. Considering the low values of dissolved solids and nearly neutral pH of Druid Lake (about 7.4 units), all concentrations of alkalinity are within an acceptable range.

Hardness - Influent concentrations of hardness (as $CaCO_3$) follow a slight yearly trend of values peaking in September, November, and December as indicated by the medians shown in Table IV-7. Effluent values only peak in September.

Concentrations at influent and effluent sample stations usually differ by about 2 mg/l. Effluent values are less than influent values during six months of the sampling period.

No limit on hardness has been set by the USPHS. High quality drinking water usually has a concentration of hardness less than 100 mg/l (Ref. IV-10). All monthly median values for hardness in Druid Lake are less than 100 mg/l).

Total chlorine - An increase in total chlorine concentrations (from 1.40 to 5.40 mg/l) occurs in influent flow during most of the sampling period (see median values in Table IV-4). Effluent concentrations do not follow the trend of influent values but are fairly stable (from 0.01 - 0.20 mg/l) with slightly higher concentrations during summer, from June through September.

A great difference exists between influent and effluent concentrations of total chlorine. When compared to influent values, effluent concentrations decrease by 1.25 - 4.99 mg/l during the year. Total chlorine is a measurement of both free and combined chlorine residuals. The loss of total chlorine from reservoir influent to effluent may be attributed to many factors. Chlorine in water is a very active chemical agent; it reacts with the many substances dissolved or suspended in water. Reducing compounds (e.g., manganese, iron, nitrites, etc.) and organic matter that are continually being transported into the reservoir via groundwater, precipitation, wind, photosynthesis, etc. exert a chlorine demand. The large reservoir

TABLE IV-6

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
DRUID LAKE - SUSPENDED SOLIDS

Month 02/75–01/76	Suspended Solids (mg/l)(1)			
	Influent		Effluent-No Chlorination	
	Range	Median	Range	Median
February	0.1–1.0	0.1	0.1–0.4	0.1
March	0.1–1.9	0.1	0.1–0.4	0.1
April	0.1–1.4	0.1	0.1–0.5	0.1
May	0.1–0.5	0.1	0.1–0.3	0.1
June	0.1–1.3	0.1	0.1–0.3	0.1
July	0.1–1.2	0.2	0.1–1.3	0.1
August	0.1–1.5	0.2	0.1–0.2	0.1
September	0.1–2.0	0.2	0.1–0.5	0.2
October	0.2–5.0	0.4	0.1–0.6	0.4
November	0.1	0.1	0.1	0.1
December	0.1–0.2	0.1	0.1–0.2	0.1
January	0.2–0.5	0.2	0.2–0.6	0.3

Note: (1) 0.1 = lower limit of detection of suspended solids.

TABLE IV-7

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
DRUID LAKE - TOTAL ALKALINITY AND HARDNESS

Month 02/75-02/76	Total Alkalinity (mg/l)[1]				Hardness (as $CaCO_3$)(mg/l)[2]			
	Influent		Effluent-No Chlorination		Influent		Effluent-No Chlorination	
	Range	Median	Range	Median	Range	Median	Range	Median
February	45-54	47	45-58	47	69-75	71	67-74	70
March	42-54	46	42-45	43	68-75	73	68-74	71
April	42-48	44	38-47	44	62-73	68	66-75	69
May	35-41	38	35-42	38	62-73	68	63-74	70
June	37-40	38	37-42	39	52-74	71	66-76	73
July	33-47	41	40-45	42	54-76	64	54-68	62
August	40-54	45	43-54	46	60-80	72	65-80	72
September	46-60	51	48-56	50	68-93	81	72-100	84
October	32-55	39	35-50	42	62-92	66	67-86	74
November	40-50	42	40-44	42	72-84	75	68-80	74
December	40-46	42	39-46	42	70-82	77	62-67	72
January	20-40	39	36-42	38	60-76	68	67-74	70

Note: (1) 1 mg/l = lower limit of detection for total alkalinity.

(2) 1 mg/l = lower limit of detection for hardness (as $CaCO_3$).

volume affords the opportunity and time for these substances to react with chlorine. Consequently various amounts of available chlorine are being removed, depending on the amount of chlorine demanding substances that are present. Additionally, sunlight dissipates chlorine in large open reservoirs. The increase in the total chlorine concentrations that occurs in the influent over the course of the study period, and the corresponding constant values of total chlorine in the effluent during the entire period indicates that a concomitant increase in the chlorine demand present in the reservoir is occurring. The incidence of sun light over the course of the study period may also be partially responsible for varying degrees of chlorine dissipation.

The USPHS has set no limits upon total chlorine concentration. However, the threshold of taste in redistilled water is about 3 mg/l (Ref. IV-10). Because chlorine is added as a disinfectant, the loss of chlorine is of primary concern.

Free chlorine - The temporal and spatial trends of free residual chlorine follow those of total chlorine (see Table IV-8). Apparently, most of total chlorine exists as free chlorine which is shown by sampling data in Table A-1 (Appendix). The difference between residual chlorine and total chlorine concentrations is usually small (Table A-1) indicating the presence of only small amounts of combined chlorine. The fact that only a small portion of the effluent total chlorine exists in the combined form (i.e., chloramine compounds) indicates a correspondingly negligible amount of ammonia is present in the reservoir as a result of the many possible contaminant transport processes. Figure IV-3 shows the yearly trend in the loss of free chlorine through the reservoir.

Because free chlorine is extremely important to disinfection of the water supply and because of the additional cost incurred by applying chlorine, the Mann-Whitney 'U' Test was used to evaluate the difference of concentrations between influent and effluent. While differences in parameter values between influent and effluent have previously been observed, no attempt was made to identify the significance of the difference. Results from the statistical analysis of free chlorine residual (Table IV-8) indicate that the probability of different concentrations between influent and effluent is greater than the 99 percent confidence level. In Table IV-8, the typical large difference between U and U shows that the confidence probability is much greater than the 99 percent probability indicated.

No limits for free chlorine residual have been set by the USPHS.

Copper - Both influent and effluent concentrations of copper show approximately the same yearly trends of higher values in late spring (May) and during fall (October) as indicated by the monthly medians in Table IV-9. Periods of higher copper concentrations do not correspond to applications of copper sulfate (an algicide) made on the following dates: 4/09/75; 5/19/75; 6/20/75; 7/21/75; 8/12/75; and 10/15/75 (see Appendix, Table A-1).

Except for a couple of months, copper concentrations usually increase by about 0.005 mg/l from influent to effluent. The large influent median value of December (0.048 mg/l) may not be indicative of copper concentrations existing in December owing to the small number of samples taken (see Table A-1).

[illegible]

[illegible]

Month	Free Chlorine Residual (mg/l)[1]							
	Sample Sites				Non-Parametric "U" Test[2]			
					Influent-Effluent, as Cl_2			
[illegible]	Influent		Effluent-No Chlorination					
	Range	Median	Range	Median	[illegible]	[illegible]	α	Probability of Unequal Conc. (%)
February	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
September	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
November	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
December	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
January	[illegible]	[illegible]	—	—	—	—	—	—

Note: (1) [illegible] mg/l = lower limit of detection for residual chlorine.

(2) Non-directional test for equal concentrations of residual chlorine at sampling sites: influent and effluent-no chlorination. [illegible]

* [illegible]

FIGURE IV-3 MONTHLY MEDIAN DIFFERENCES (EFFLUENT MINUS INFLUENT)
FREE CHLORINE RESIDUAL FOR HIGHLAND RESERVOIR

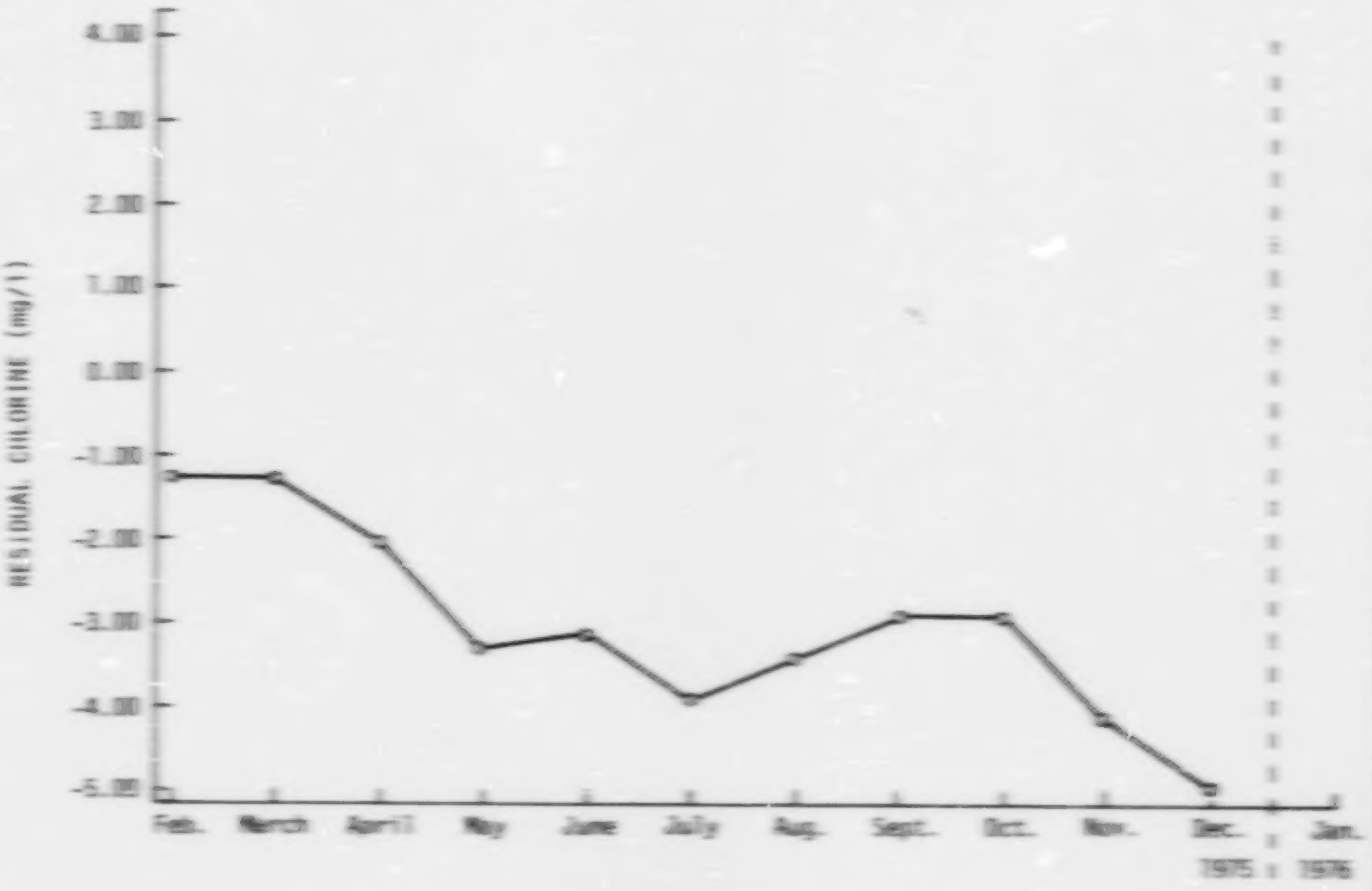


TABLE IV-9

MONTHLY MEDIANS AND RANGE OF ROUTINE WATER SAMPLING DATA
DRUID LAKE - NITRATE AND COPPER

Month 02/75–01/76	Nitrate (as N)(mg/l)[1]				Copper (mg/l)[2]			
	Influent		Effluent-No Chlorination		Influent		Effluent-No Chlorination	
	Range	Median	Range	Median	Range	Median	Range	Median
February	0.9–1.1	0.9	0.7–0.9	0.9	0.002–0.016	0.008	0.001–0.010	0.002
March	0.7–1.2	0.9	0.9–1.1	1.0	0.001–0.010	0.006	0.003–0.010	0.006
April	0.9–1.2	1.1	0.9–1.2	1.0	0.003–0.012	0.004	0.002–0.007	0.004
May	0.8–1.0	0.9	0.7–0.9	0.8	0.004–0.061	0.035	0.024–0.060	0.040
June	0.8–1.3	0.9	0.7–1.2	0.9	0.004–0.040	0.012	0.002–0.060	0.023
July	0.7–1.0	0.8	0.7–0.9	0.7	0.010–0.022	0.010	0.010–0.042	0.015
August	0.7–0.9	0.7	0.7–0.8	0.7	0.002–0.020	0.010	0.007–0.015	0.005
September	0.5–0.8	0.7	0.5–1.0	0.7	0.001–0.015	0.006	0.001–0.06	0.007
October	0.8–1.4	1.0	0.6–1.1	0.9	0.010–0.140	0.020	0.002–0.030	0.040
November	0.3–1.4	1.0	0.5–1.5	1.4	0.001–0.005	0.003	0.002–0.010	0.005
December	0.9–1.9	1.6	1.5–1.9	1.6	0.010–0.070	0.040	0.010–0.070	0.010
January	1.2–1.8	1.4	0.9–1.7	1.2	0.010–0.020	0.010	0.010–0.020	0.010

Note: (1) 0.01 mg/l = lower limit of detection for nitrate (as N).

(2) 0.001 mg/l = lower limit of detection for copper.

The USPHS has recommended a limit on copper of 1.0 mg/l for domestic water supplies. This limit is primarily based on threshold concentrations of taste which are in the range of 1.0 - 2.0 mg/l. All reported copper concentrations in Druid Lake are much less than 1.0 mg/l.

Lead - The yearly trends of influent and effluent lead concentrations, indicated by the medians shown in Table IV-10, are similar to the higher lead values during spring and early winter.

A possible explanation for these high lead values can be found by evaluating monthly composite air analyses performed by the Baltimore Health Department at a station about 4 Km (2.5 miles) from Druid Lake. The uncovered holding reservoir (receiving water, immediately after treatment) from which water flows to Druid Lake is located in the immediate vicinity of this station. Therefore, the results of the air analyses may be indicative of ambient air quality near both reservoirs. Results of lead analyses at this location are the following (Ref. IV-12).

January, 1975 = 1.103 micrograms/cu m. lead
February = 0.881
March = 0.761
April = 0.618
May = 0.806
June = 0.429
July = 0.723
August = 0.559
September = 0.796
October = 1.005
November = 1.627
December = 1.125
January, 1976 = 0.977

These results indicate generally higher values during early spring, fall, and winter which affect lead concentrations in Druid Lake by rain or wind deposition. Figure IV-4 shows that except for the month of January, small differences of 0.003 mg/l of lead or less exists between influent and effluent monthly data medians. The reason for the relatively large increase of effluent lead concentration during January is unknown.

Evaluation of differences between influent and effluent concentrations was performed by testing for significance using the Mann-Whitney 'U' Test. Results indicate that the probability of dissimilar concentrations during all months is less than 90 percent (see Table IV-10). Thus, even the difference in lead values during January has less than a 90 percent probability of occurring.

The USPHS has set a limit of 0.05 mg/l lead concentration for drinking water. All lead values in Druid Lake are less than 0.05 mg/l.

[illegible]

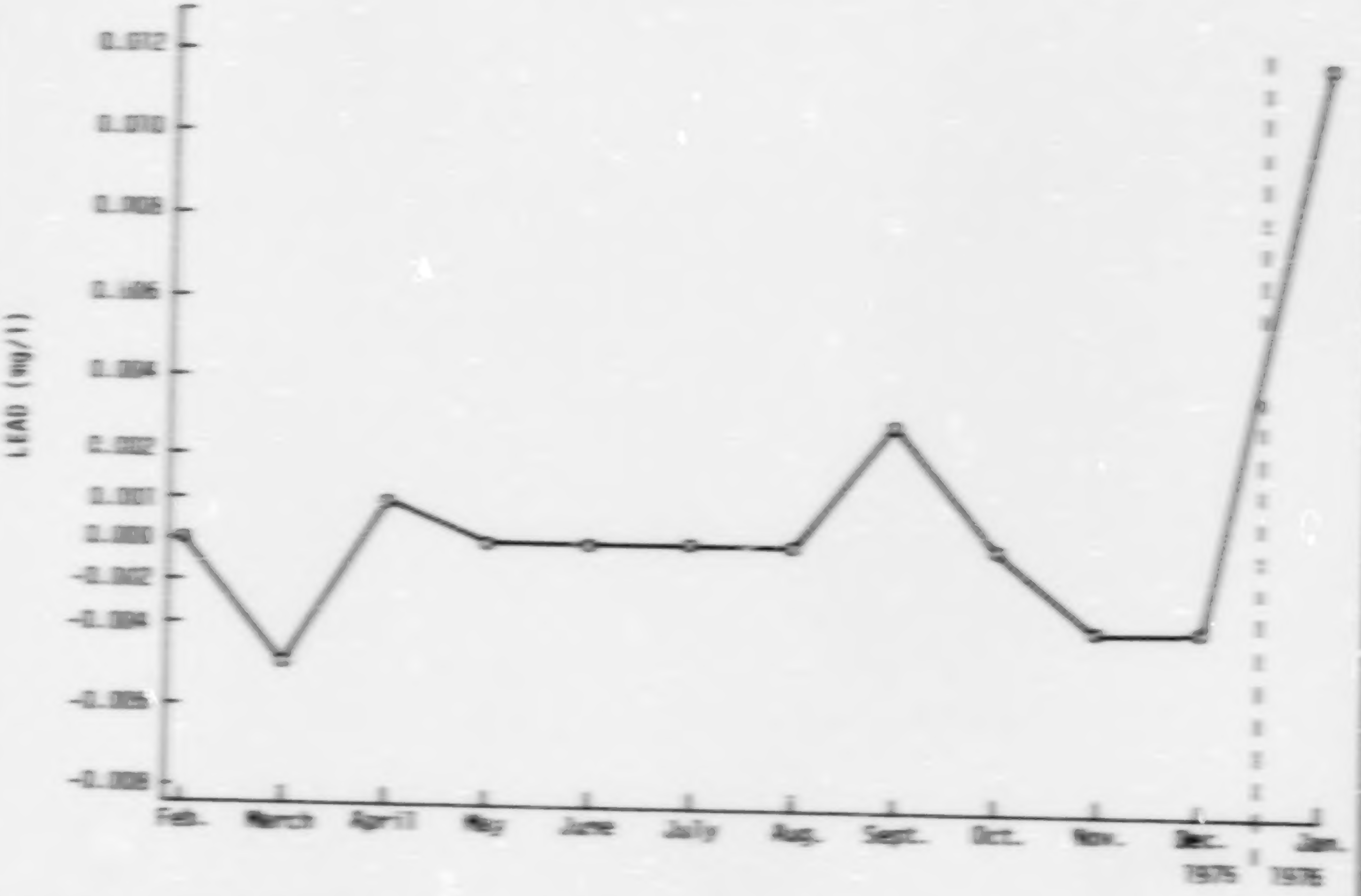
[illegible]

Month	Lead (mg/l)[1]							
	Sample Sites				Mann-Whitney "U" Test[2]			
					Influent-Effluent, [illegible]			
[illegible]	Influent		Effluent-to Chlorination					
	Range	Median	Range	Median	U_c	U_a	α	Probability of Unequal Conc. (%)
February	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	73.0	35	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	57.5	42	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	75.5	47	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	66.5	51	[illegible]	[illegible]
August	[illegible]	[illegible]	[illegible]	[illegible]	67.0	51	[illegible]	[illegible]
September	[illegible]	[illegible]	[illegible]	[illegible]	65.0	51	[illegible]	[illegible]
October	[illegible]	[illegible]	[illegible]	[illegible]	62.5	56	[illegible]	[illegible]
November	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
December	[illegible]	[illegible]	[illegible]	[illegible]	66.5	26	[illegible]	[illegible]
January	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Note: (1) [illegible]

(2) [illegible]

FIGURE IV-4 MONTHLY MEDIAN DIFFERENCES (EFFLUENT MINUS INFLUENT)
LEAD FOR DRUID LAKE



Ammonia - Measurements of ammonia vary little either seasonally or spatially with most values near or below the analytical limit of detection, 0.02 mg/l (see Appendix, Table A-1). Slightly higher concentrations were observed during the month of October, but the significance of this difference is doubtful.

While the USPHS has set no limits on ammonia concentration, a generally accepted limit indicating sanitary conditions is approximately 0.04 - 0.08 mg/l ammonia as N (Ref. IV-10). Concentrations of both influent and effluent sporadically exceed this limit.

Nitrate - Both influent and effluent concentrations of nitrate show a slight yearly trend of smaller values during summer and larger values during early winter, indicated by the medians shown in Table IV-9. While a tendency exists for concentrations to remain the same or decrease from influent to effluent, the difference in values is small, typically about 0.1 mg/l.

The USPHS has recommended a limit of 10 mg/l nitrate as N. All concentrations of nitrate in Druid Lake are much less than 10 mg/l.

Total phosphate - A slight seasonal trend exists, where influent and effluent concentrations of total phosphate (as PO_4) increase during late spring and late summer (Table IV-11). Influent and effluent concentrations are similar with monthly median values typically exhibiting either no difference between sample stations or a slight decrease of effluent median concentrations. Spatial decreases of median concentration are only 0.01 mg/l. Isolated, high concentrations occur in September and October.

No limits upon total phosphate have been set by the USPHS. The presence of phosphate in Druid Lake is of primary importance as a bio-nutrient. Threshold phosphate requirements for biological growth depend upon climate and the chemical and physical character of the water. Dissolved (soluble) inorganic phosphate (usually orthophosphate) is the most readily assimulated form of phosphate. Comparison of total phosphate with soluble orthophosphate concentrations indicate that most of total phosphate is composed of soluble orthophosphate. Concentrations of inorganic phosphate may occasionally be in excess of threshold nutrient requirements, as discussed in the following section.

Soluble orthophosphate - Both influent and effluent concentrations of soluble orthophosphate show an increase in monthly median values (Table IV-11) during late spring and late summer. Only a few monthly data medians show any change between influent and effluent values and these differences are only about 0.1 mg/l.

The USPHS has set no limits on concentration of soluble orthophosphate. This inorganic form of phosphate is a more specific plant nutrient than total phosphate. Comparison of total phosphate median concentrations with soluble orthophosphate medians indicates that most of total phosphate is composed of soluble orthophosphate. A suggested maximum concentration

TABLE IV-11

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
[illegible] LAKE - TOTAL PHOSPHATE AND SOLUBLE ORTHO PHOSPHATE

Month 02/75-01/76	Total Phosphate (as PO_4)(mg/l)(1)				Soluble Ortho Phosphate (as PO_4)(mg/l)(2)			
	Influent		Effluent-No Chlorination		Influent		Effluent-No Chlorination	
	Range	Median	Range	Median	Range	Median	Range	Median
February	0.02-0.05	0.03	0.01-0.03	0.01	0.01-0.05	0.02	0.01-0.02	0.01
March	0.01-0.06	0.03	0.01-0.03	0.02	0.01-0.06	0.02	0.01-0.04	0.03
April	0.03-0.08	0.04	0.02-0.08	0.04	0.02-0.08	0.03	0.02-0.06	0.04
May	0.01-0.19	0.09	0.02-0.10	0.08	0.01-0.10	0.06	0.01-0.10	0.07
June	0.01-0.09	0.05	0.01-0.12	0.05	0.01-0.07	0.03	0.01-0.06	0.03
July	0.01-0.06	0.03	0.01-0.05	0.03	0.01-0.06	0.02	0.01-0.05	0.02
August	0.03-0.05	0.05	0.03-0.05	0.05	0.03-0.05	0.05	0.03-0.05	0.05
September	0.01-0.07	0.05	0.01-0.42	0.05	0.01-0.07	0.05	0.01-0.12	0.05
October	0.01-0.25	0.12	0.01-0.20	0.02	0.01-0.12	0.02	0.01-0.12	0.02
November	0.01-0.12	0.03	0.01-0.08	0.02	0.01-0.12	0.02	0.01-0.05	0.02
December	0.01-0.06	0.01	0.01-0.06	0.01	0.01-0.05	0.01	0.01-0.05	0.01
January	0.01-0.10	0.02	0.01-0.43	0.02	0.01-0.06	0.01	0.01-0.02	0.01

Note: (1) 0.01 mg/l = lower limit of detection for total phosphate (as PO_4)

(2) 0.01 mg/l = lower limit of detection for soluble ortho phosphate (as PO_4)

of inorganic phosphorus is 0.01 mg/l which can be permitted without encouraging plant growth (Ref. IV-10). If this limit of phosphorus is expressed in terms of phosphate then the maximum concentration is about 0.03 mg/l (as PO_4). The median concentrations of orthophosphate shown in Table IV-11 indicate that the suggested limit of 0.03 mg/l is equaled or exceeded by influent values of five months and by effluent values for six months.

Total coliforms - Measurements of total coliform bacteria (Table IV-12) indicate that at all sampling stations during the entire sampling period, total coliforms are practically nonexistent.

The USPHS limits the presence of coliform organisms in a potable water to one coliform organism per 100 ml if the membrane filter technique is used; if the multiple tube fermentation technique (MPN) is used, not more than 10 percent of the standard 10 ml samples examined in any single month shall show the presence of the coliform group. In this study, coliform bacteria were measured by the MPN test during the first half (February 1 to June 20) of the sampling period, and then for the remainder of the period the membrane filter technique was used. The MPN data collected indicated the absence of coliform bacteria except during the month of April at sample point D-2. Less than three percent of the samples examined showed positive for coliforms. In either case, the MPN of these results is shown as <2/100 ml. Data collected using the membrane filter technique consistently had values of 0.05 coliform colonies per 100 ml. Analytical results indicate, therefore, that the Druid Lake water meets USPHS standards. All of the total coliform data listed in Appendix Table A-1 shows values less than 2 MPN/100 ml because this is the nominal minimum MPN per 100 ml sample that can be reported from the negative tube results (e.g. all negative tubes is still considered <2 MPN/100 ml).

Fecal coliforms - Concentrations of fecal coliform bacteria (Table IV-13) indicate that these coliforms exist at densities less than the limit of analytical detection during the sampling period.

No USPHS limit exists for fecal coliforms. As with the total coliform analyses, the fecal coliform analyses over the course of the study period were done by two procedures: the multiple tube fermentation test for fecal coliforms and the membrane filter test for fecal coliforms. The results of the multiple tube fermentation tests are shown as MPN per 100 ml. Since these were all negative, the results are shown nominally as <2 MPN per 100 ml. Analytical results using the membrane filter technique (after 20 June 1975) were also negative and these are shown as <0.05 fecal colonies per 100 ml. Although both methods produced negative results concerning the presence of fecal coliform bacteria, the data are shown differently due to the inherent detection limits of each technique.

Total standard plate count - Monthly median concentrations of bacteria at the influent sampling station (Table IV-14) show no yearly change with values less than or equal to the minimum analytical detection limit (1 colony/ml). Effluent medians during the sampling period indicate an increase in numbers of bacteria during late spring and mid-autumn. This increase coincides with the decrease of free residual chlorine found during the same periods (Table IV-8) in the effluent of Druid Lake. Compared to influent

TABLE IV-12

MONTHLY MEDIAN AND RANGE OF WASTE WATER SAMPLING DATA
DAVID LAKE - TOTAL COLIFORMS

Month 02/75–01/76	Total Coliforms (colonies per 100 ml)					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February (1)	<2	<2	<2	<2	<2	<2
March (1)	<2	<2	<2	<2	<2	<2
April (1)	<2	<2	<2	<2	<2	<2
May (1)	<2	<2	<2	<2	<2	<2
June (1)	<2	<2	<2	<2	<2	<2
July (2)	0.05	0.05	0.05	0.05	0.05	0.05
August (2)	0.05	0.05	0.05	0.05	0.05	0.05
September (2)	0.05	0.05	0.05	0.05	0.05	0.05
October (2)	0.15	0.05	0.05	0.05	0.05	0.25
November (2)	0.05	0.05	0.05	0.25	0.05	0.05
December (2)	0.05	0.05	0.05	0.05	0.05	0.05
January (2)						

Notes: (1) MPN of colonies per 100 ml. in multiple tube fermentation tests.

(2) Coliform colonies counted per 100 ml. in membrane filter tests.

TABLE III-13

MONTHLY MEDIANS AND RANGE OF ROUTINE WATER SAMPLING DATA
DRUID LAKE - FECAL COLIFORMS

Month 02/75-01/76	Fecal Coliforms (colonies per 100 ml)					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February (1)	<2	<2	<2	<2	<2	<2
March (1)	<2	<2	<2	<2	<2	<2
April (1)	<2	<2	<2	<2	<2	<2
May (1)	<2	<2	<2	<2	<2	<2
June (1)	<2	<2	<2	<2	<2	<2
July (2)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
August (2)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
September (2)	<0.25	<0.05	<0.05	<0.05	<0.05	<0.05
October (2)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
November (2)	<0.05	<0.25	<0.05	<0.05	<0.05	<0.05
December (2)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
January (2)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Notes: (1) MPN of fecal colonies per 100 ml. in multiple tube fermentation (Fecal Coli.) test.

(2) Fecal coliform colonies counted per 100 ml. in membrane filter (Fecal Coli.) test.

[illegible]

[illegible]

Month	[illegible]													
	Sample Sites						[illegible]							
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination		[illegible]				[illegible]			
[illegible]	Range	Median	Range	Median	Range	Median	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
February	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
September	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
November	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
December	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
January	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

FIGURE IV-5 MONTHLY MEDIAN DIFFERENCES (EFFLUENT MINUS INFLUENT)
TOTAL STANDARD PLATE COUNT FOR DRUID LAKE

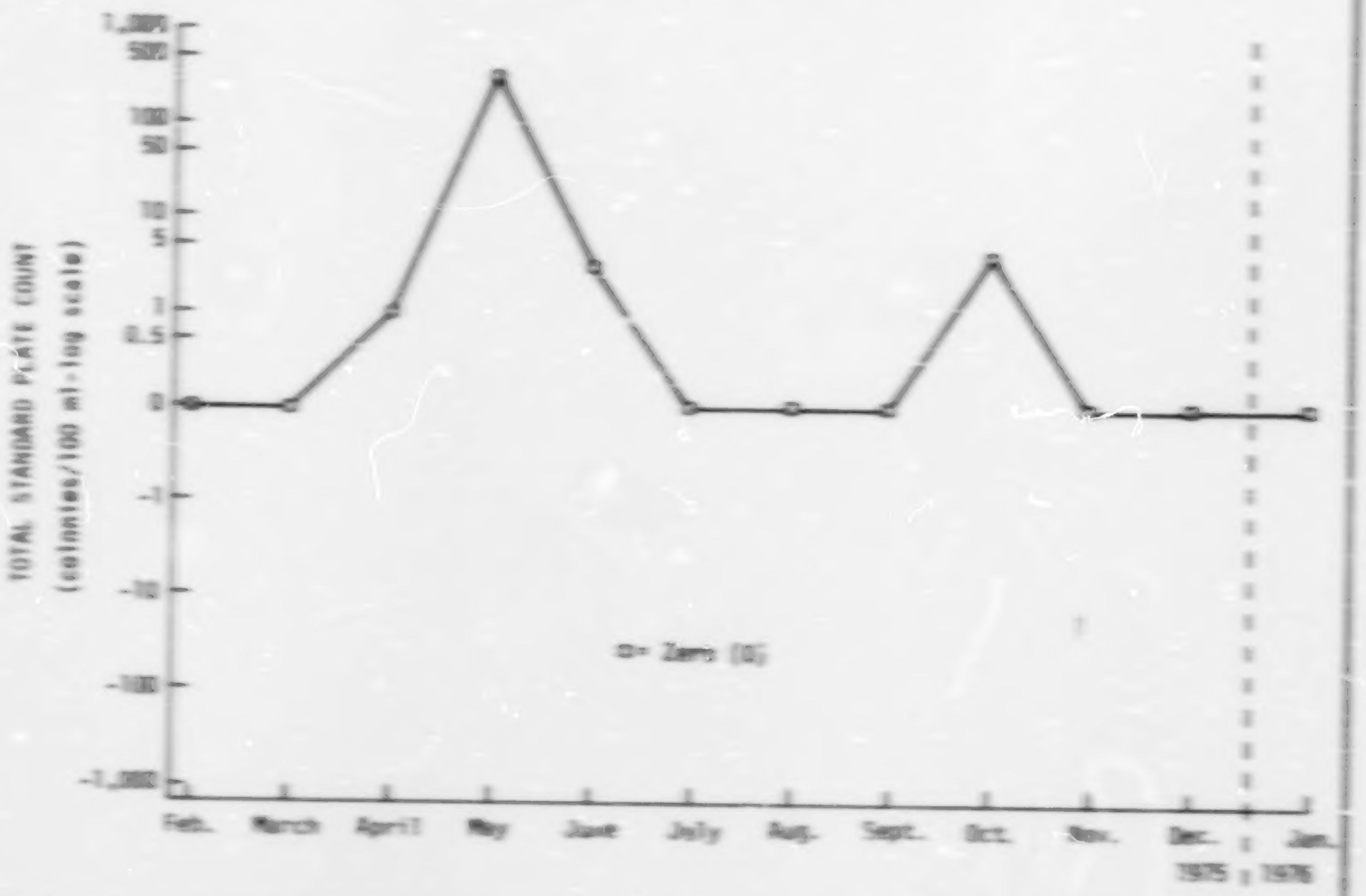
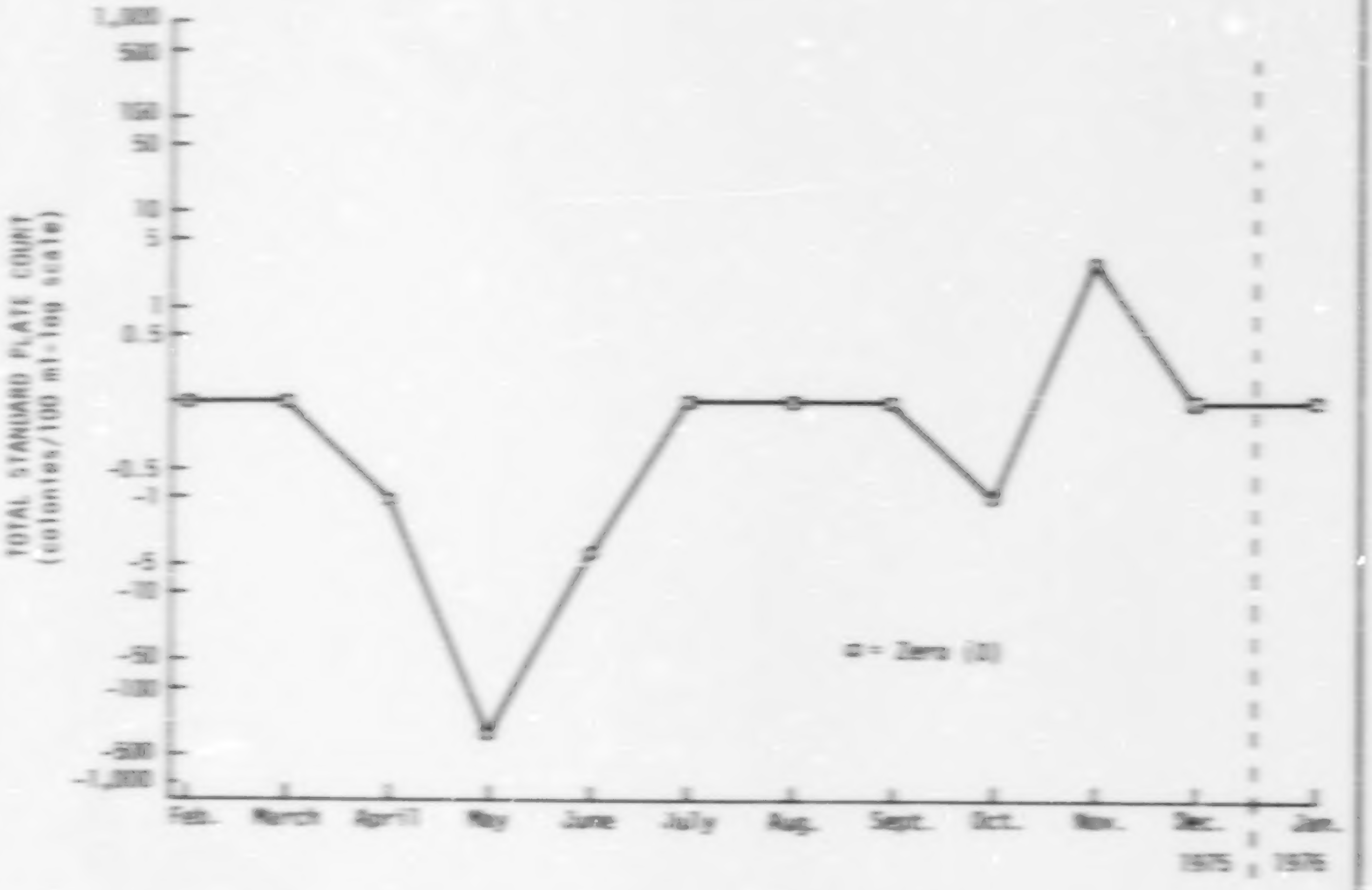


FIGURE IV-6 MONTHLY MEDIAN DIFFERENCES (POSTCHLORINATION MINUS EFFLUENT)
TOTAL STANDARD PLATE COUNT FOR DRUID LAKE



concentrations, the increase of effluent values is occasionally dramatic with peaks of up to 1600 colonies/ml (Appendix, Table A-1). The difference between influent and effluent medians is generally small except for the month of May (Figure IV-5). After postchlorination, bacterial concentrations usually decrease from their prechlorination values (Figure IV-6) to low concentrations less than or equal to the minimum limit of detection. However, concentrations during the months of October and November increase above this limit.

The Mann-Whitney 'U' Test was used to determine the significance of the difference in concentrations between influent and prechlorination effluent, and effluent before and after postchlorination. Results from the statistical analysis of influent/prechlorination effluent data (Table IV-14) show that only during late spring is the probability of different bacteria concentrations at the two stations greater than 90 percent. However, comparison of U_M and U_a indicate that during other months, the probability of unequal concentrations is not substantially less than 90 percent. Results of the 'U' test for differences between concentrations at points of effluent before and after postchlorination indicate probabilities greater than 90 percent of unequal concentrations occurring during spring. As in the previous test of significance the probability of dissimilar concentrations at influent and effluent sampling stations during the remainder of the year is not substantially less than 90 percent.

Increases in the concentrations of bacteria are probably a function of decreases in free residual chlorine concentrations. Postchlorination decreases bacteria concentration. However, a slight net gain over influent bacteria density appears to exist.

The USPHS has not set limits upon bacteria density as indicated by the total standard plate count procedure.

Phytoplankton - All measurements of phytoplankton concentrations prove to be considerably less (Appendix, Table A-1) than the generally accepted amount which ordinarily defines the existence of an algae bloom: 500 organisms/ml. (Ref. IV-13). Influent concentrations of phytoplankton (Table IV-15) are highest from late winter through the summer. Effluent concentrations before postchlorination are higher during early spring and late fall with lowest values during summer. Phytoplankton densities generally increase from influent to effluent. However, the period of greatest increase only shows a median change of from 3 to 13 organisms/ml occurring in late fall and early winter (Figure IV-7). Monthly median concentrations of phytoplankton in reservoir effluent after postchlorination show increases during the year similar to prechlorination effluent. Densities are higher during early spring and late fall. Phytoplankton effluent median densities generally show a slight increase after postchlorination (Figure IV-8) of between 1 to 14 organisms/ml. These measurements may include organisms which have been killed by chlorine.

The Mann-Whitney 'U' Test was also used to determine the significance of the difference in concentrations between influent and prechlorination effluent, and effluent before and after postchlorination. Results from testing influent/prechlorination effluent (Table IV-15) show that during

[illegible]

[illegible]

Month	Phytoplankton (equivalents)[1]													
	Sample Sites						Mann-Whitney "U" Test[2]							
	Influent		Effluent–No Chlorination		Effluent–Post Chlorination		Influent-Effluent, No Cl_2				Effluent, No Cl_2-Effluent, Post Cl_2			
[illegible]	Range	Median	Range	Median	Range	Median	U_a	U_b	α	Probability of Unequal Conc. (%)	U_a	U_b	α	Probability of Unequal Conc. (%)
February	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
September	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
November	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
December	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
January	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

[illegible]

FIGURE IV-7 MONTHLY MEDIAN DIFFERENCES (EFFLUENT MINUS INFLUENT)
PHYTOPLANKTON FOR DRUID LAKE

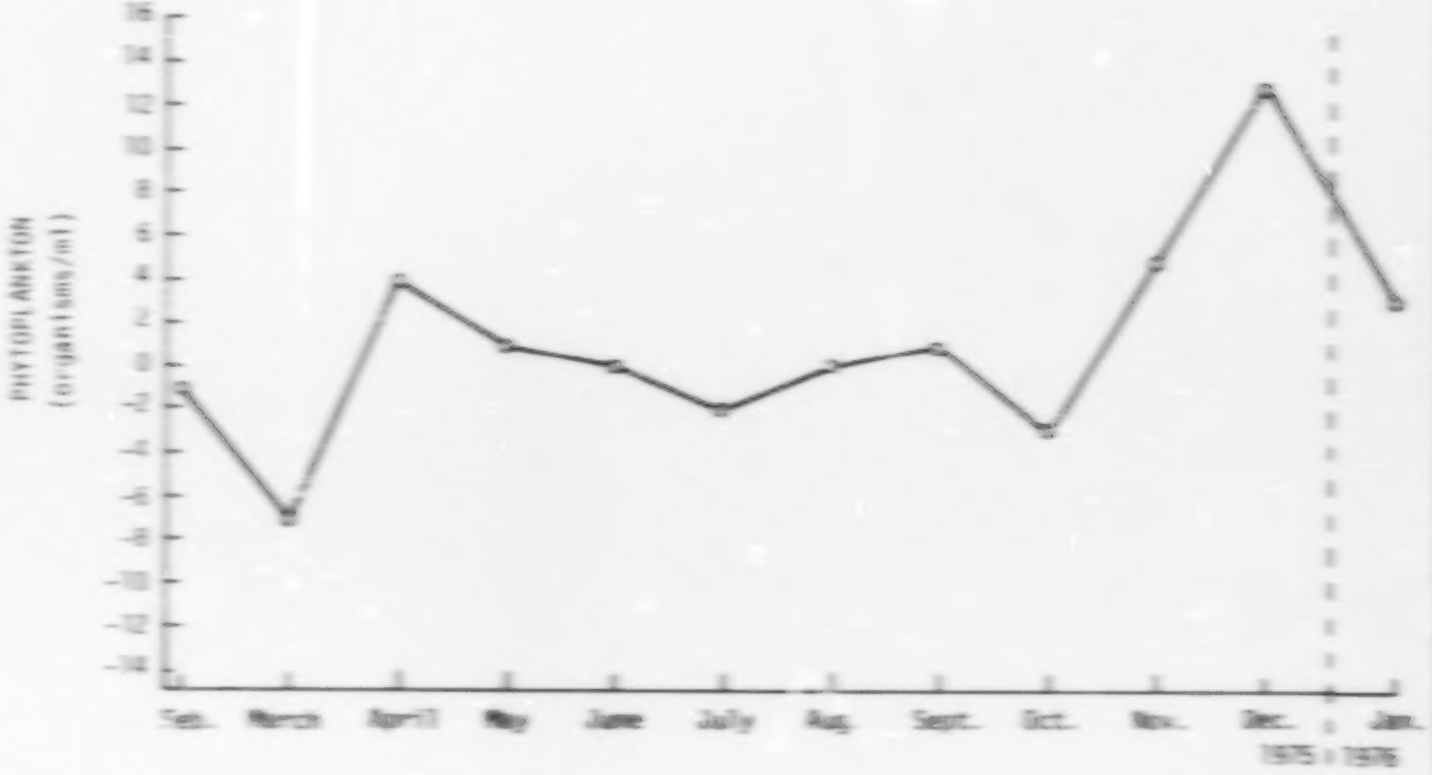
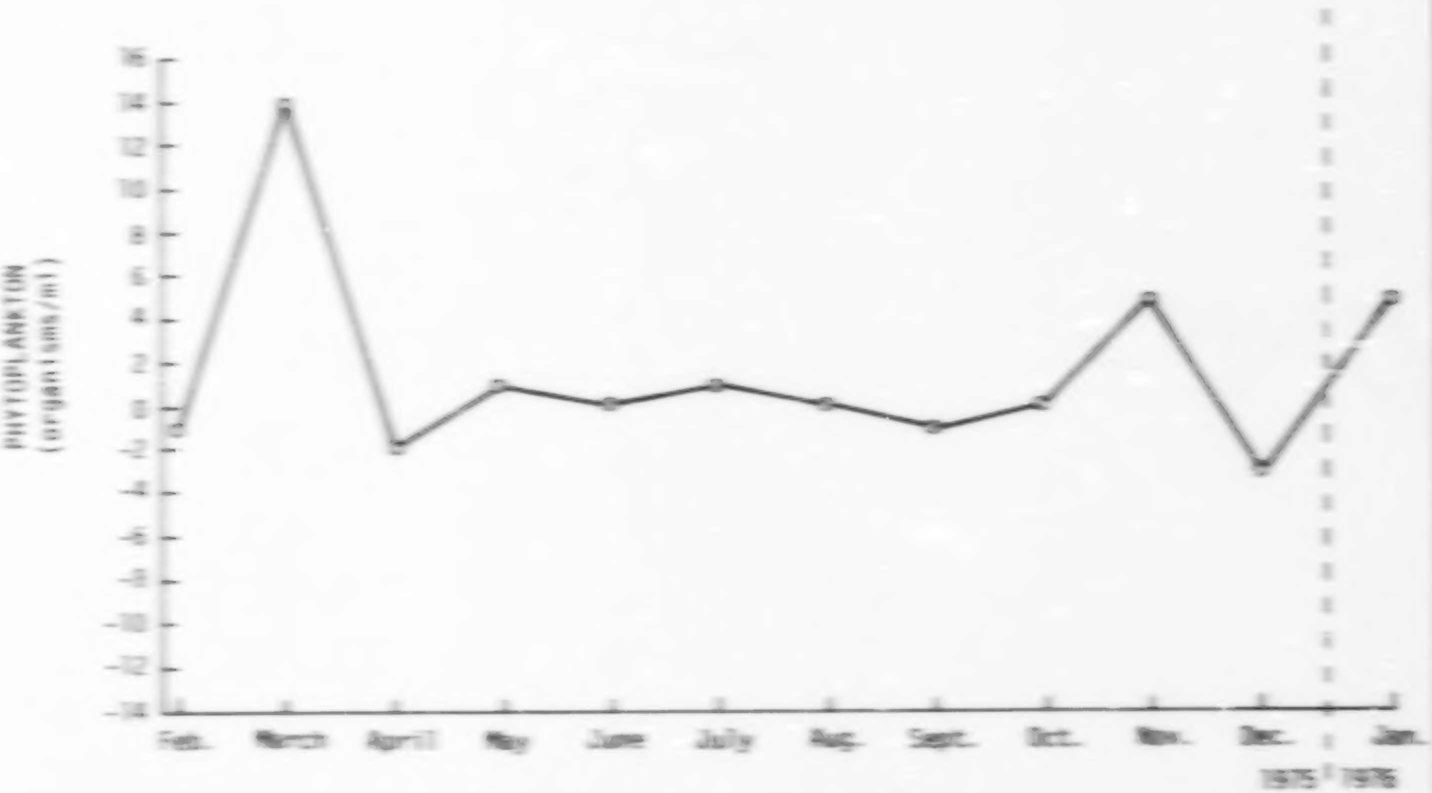


FIGURE IV-8 MONTHLY MEDIAN DIFFERENCES (POSTCHLORINATION MINUS EFFLUENT)
PHYTOPLANKTON FOR DRUID LAKE



the months of April, November, and December, the probability of unequal phytoplankton densities is greater than 90 percent. The difference in concentration is most significant during late fall. Results from analysis of concentration differences between points of effluent before and after postchlorination indicate probabilities greater than 90 percent of unequal concentrations occurring during April and May. However, these differences are conflicting with an observed decrease in April and an increase during May. A relatively large median difference exists during March but the overall thrust of the data is similar at both stations. Postchlorination does not appear to greatly influence phytoplankton densities.

The USPHS has no limits upon algae density. Algae principally degrade water quality by causing taste and odor problems, or increased turbidity if present in high numbers. The algae most commonly believed to cause taste and odor problems are green algae (Chlorophyceae) and blue-green algae (Cyanophyceae). The principal algae found in Druid Lake during the sampling period are the following: Chlorophyceae-*Closterium* and *Cosmarium*; Cyanophyceae-*Anabaena*, *Coelosphaerium*, and *Oscillatoria*; and Diatomaceae (diatoms)-*Asterionella*, *Amphora*, *Fragilaria*, *Navicula*, *Melosira*, and *Stauroneis*. Under proper growth conditions, taste and odor problems could occur.

Special Sampling Program

Total organic carbon - Both influent and effluent measurements of total organic carbon (TOC) generally follow the same yearly trend (see Table IV-16). Increases of concentration primarily occur during July and August with smaller increases during January, March, and early April. Decreases of concentration occur during June and December.

Even though both influent and effluent values exhibit similar yearly trends, effluent concentrations are almost always lower than influent values. Effluent concentrations show the greatest decrease (about 25 percent) during May, July, August, and September.

No limits have been set for TOC by the USPHS. Total organic carbon is a gross measure of organic carbon present in the water and usually reflects specific organic parameters such as phytoplankton, and various forms of organic solids.

Trace Metals - Analysis for trace metals was basically performed on metals which have proven to be deleterious to health. Measurements of trace metals are listed in Table IV-17. In Table IV-17, minimum limits of detection, denoted by an asterisk, may change for a given parameter because of using different minimum concentration standards in the atomic absorption analytical technique used.

All measurements of barium are less than or equal to the lower limit of analytical detection. Virtually no difference in concentration occurs at either the influent or effluent sampling station during the sampling period. The USPHS has set a maximum limit of 1.0 mg/l with which all measurements comply.

Chromium concentrations are the same at both sample stations during the year. All measurements are less than or equal to the minimum limit of

TABLE IV-16

TOTAL ORGANIC CARBON SAMPLING RESULTS FOR DRUID LAKE, BALTIMORE, MD.

Date Sample Collected	Total Organic Carbon (mg/l)	
	Influent	Effluent
3/31/75	1.29	1.23
4/03/75	1.27	1.24
4/10/75	1.56	1.25
4/17/75	1.26	0.81
4/24/75	1.05	1.00
5/01/75	0.95	0.94
5/09/75	1.08	0.83
5/14/75	1.10	0.70
5/23/75	1.43	0.97
5/28/75	1.22	0.91
6/06/75	0.91	0.94
6/13/75	0.70	0.64
6/20/75	0.81	0.78
7/04/75	1.68	1.60
7/11/75	*	*
7/18/75	1.55	1.31
7/25/75	1.40	1.2[illegible]
8/01/75	1.68	1.20
8/08/75	1.96	1.44
8/15/75	1.50	1.07
8/22/75	1.68	1.52
8/29/75	1.31	1.08
9/05/75	2.13	1.81
9/12/75	1.16	0.95
9/19/75	1.58	0.95
10/03/75	1.17	1.05
10/17/75	1.16	0.97
10/24/75	1.19	0.92
10/31/75	1.23	1.05
11/07/75	0.88	0.87
11/13/75	1.38	1.52
11/20/75	0.91	1.73
11/26/75	0.92	0.91
12/04/75	0.85	0.87
12/11/75	0.66	0.66
12/18/75	0.80	0.81
12/26/75	0.97	0.97
12/31/75	1.26	1.13
1/08/76	1.30	0.93
1/16/76	1.67	1.13
1/22/76	1.26	1.39
1/29/76	1.21	1.19

Note: (1) See Figure IV-2 for location of sampling sites.

TABLE [illegible]

TRACE METAL SAMPLING RESULTS

FOR [illegible] LAKE

Date of Sample Collection	Trace Metals (mg/l)(1)									
	Barium		Chromium		Silver		Copper		Manganese	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
[illegible]75	* [illegible]	* [illegible]	* 0.005	* 0.005	* 0.01	* 0.01	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* 0.005	* 0.01	* 0.01	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* 0.005	* 0.01	* 0.01	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* 0.005	* 0.01	* 0.01	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* 0.005	* 0.01	* 0.01	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* 0.005	* [illegible]	* [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* [illegible]	* [illegible]	* [illegible]	* [illegible]	* [illegible]	* [illegible]	* [illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* 0.005	* 0.01	* 0.01	[illegible]	* [illegible]	* [illegible]	* [illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* 0.005	* 0.01	* 0.01	[illegible]	* [illegible]	* [illegible]	* [illegible]
[illegible]75	* 0.20	* 0.20	* 0.005	* 0.005	* 0.01	* 0.01	* [illegible]	* [illegible]	* [illegible]	[illegible]
[illegible]75	* 0.20	—	* 0.005	—	* 0.01	—	* [illegible]	—	* [illegible]	—
[illegible]75	* 0.20	—	* 0.005	—	* 0.01	—	* [illegible]	—	* [illegible]	—

* Concentration is less than the indicated value

Note (1) See Figure [illegible] for location of sampling sites.

TABLE IV-17 (continued)

TRACE METAL SAMPLING RESULTS

FOR [illegible] LAKE

Date of Sample Collection	Trace Metals (mg/l)[1]									
	Lead		Iron		Cadmium		Zinc		Mercury	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	—	[illegible]	—	[illegible]	—	[illegible]	—	[illegible]	—
[illegible]	[illegible]	—	[illegible]	—	[illegible]	—	[illegible]	—	[illegible]	—

* Concentration is less than the indicated value.

Note: (1)
See Figure IV-[illegible] for location of sampling sites.

analytical detection. A maximum limit of 0.05 mg/l for hexavalent chromium was set by the USPHS. The atomic absorption analytical technique used in this study measures total chromium. The USPHS limit is met because all values of total chromium are less than 0.05 mg/l.

Every measurement of silver is less than or equal to the lower limit of analytical detection. Even though the concentrations in Table IV-17 change during the year at both influent and effluent sample stations, all silver values may actually be the same as the lowest value (0.01 mg/l). This possibility is irresolvable owing to limitations of the analytical technique. Silver concentrations do not change from influent to effluent for a particular sample date. USPHS Drinking Water Standards limit silver concentration to 0.05 mg/l. All silver measurements in Druid Lake are less than this limit except those during the months of July and August whose compliance with the standard is not known owing to the large magnitude of the lower limit of detection.

Both influent and effluent concentrations of copper are fairly erratic during the sampling period. No particular trend of concentration change between influent and effluent sample stations is discernible. Comparison of the copper analytical results in Table IV-17 and results from the routine sampling program in Table A-1 (Appendix) indicate different concentrations for both influent and effluent on almost every sample date. The greatest difference occurs at the influent station (0.168 mg/l) on 4 July 1975 and at the effluent station (0.238 mg/l) on 4 March 1975. The USPHS has recommended the limit on copper to be 1.0 mg/l which is not violated by any of the analytical results.

A slight yearly trend of manganese concentrations exists where larger values occur during spring at both influent and effluent stations. Differences between influent and effluent values are small or nonexistent. The USPHS has recommended a limit of 0.05 mg/l for manganese. All reported concentrations are less than this standard except during the month of August. The concentration during August cannot be distinguished from values less than 0.06 mg/l.

All concentrations of lead are less than or equal to the minimum limit of analytical detection. Most of the concentrations for both influent and effluent show little change during the year or between sampling stations. Comparison of the lead analytical results in Table IV-17 and results from the routine sampling program in Table A-1 (Appendix) indicate approximately equal results on the same sample date for influent dates - 2/03/75, 7/04/75, 8/01/75, and 9/03/75, and effluent dates - 7/04/75, 9/03/75, and 11/03/75. The other results show large differences. The USPHS has set a limit on lead concentrations of 0.05 mg/l which is not exceeded by any measurement of lead in Druid Lake.

Measurements of iron for both influent and effluent are generally erratic during the sampling period. However, effluent concentrations usually follow the same change in magnitude that influent concentrations display even though effluent values tend to be slightly less than influent values. The Drinking Water Standards of the USPHS recommend a limit of 0.3 mg/l for iron. All measurements of iron in Druid Lake are less than this limit.

All measurements of cadmium at both influent and effluent sampling stations are less than or equal to the lower limit of detection, 0.002 mg/l. Every concentration is equal to 0.002 mg/l, thus showing no temporal or spatial change. The USPHS has set a limit of 0.01 mg/l on cadmium concentration. No measurement of cadmium in Druid Lake exceeds this limit.

Concentrations of zinc follow no discernible yearly trend at either influent or effluent sampling stations. Values greater than the limit of detection increase from influent to effluent or do not change at all. The USPHS limits the concentration of zinc in drinking water to 5 mg/l. Measurements of zinc comply with this mandatory limit.

Every concentration of mercury at both influent and effluent sampling stations is less than or equal to the minimum limit of detection (0.0005 mg/l) except for an effluent concentration (0.0009 mg/l) on 10/01/75. No limit upon mercury has been set by the USPHS. The National Interim Primary Drinking Water Standards define the maximum level of mercury as 0.002 mg/l (Ref. IV-8).

Radiochemical isotopes - Radiation from radioactive substances in domestic water supplies is harmful to human health. The principal criteria by which radioactivity of domestic water is judged are: (1) alpha emitters, specifically, radium isotope 226 (Ra-226); and (2) beta emitters, both gross beta emitters and, specifically, strontium isotope 90 (Sr-90). Alpha particles have low body penetration but are highly dangerous when ingested and deposited within the body. Beta particles have moderate body penetration and are moderately harmful. Occasionally gamma radiation is monitored in water supplies but even though gamma rays are deeply penetrating, they are relatively less damaging than alpha or beta particles.

Radioactivity sampling results for Druid Lake are presented in Table IV-18. Total solids were measured along with radioactivity to indicate the amount of solids in the water which may in part be responsible for measured radioactivity. The total solids results are about 50 mg/l (26 percent) greater than the results of the routine sampling program (see Appendix, Table A-1).

The USPHS Drinking Water Standards set the following maximum limits on radioactivity:

(1) gross beta = 1,000 picoCurie/l (pCi/l);
(2) Sr-90 = 10 pCi/l; and
(3) Ra-226 = 3 pCi/l.

TABLE IV-18

RADIOACTIVITY SAMPLING RESULTS FOR DRUID LAKE, BALTIMORE, MD.

Date Sample Collected	Sample[4] Site Location	Date Sample Counted	Total Solids mg/l	Activity (picoCurie/ml)[1]				
				Gross[2] Beta	Gross[3] Alpha	Sr-90	Ra-226	Specific Gamma
2/03/75	Influent	–	194.0	1.9 ± 55%	<2.0	–	–	Not Detectable
2/11/75	Influent	–	202.0	2.9 ± 43%	<2.0	<0.5	0.10 ± 12%	Not Detectable
5/01/75	Influent	5/17/75	110.0	1.5 ± 64%	<2.0	–	–	Not Detectable
5/05/75	Effluent	5/15/75	256.0	2.2 ± 47%	<2.0	–	–	Not Detectable
8/01/75	Influent	8/08/75	168.0	2.9 ± 33%	<2.0	–	–	Not Detectable
8/01/75	Effluent	8/15/75	215.4	1.7 ± 71%	<2.0	–	–	Not Detectable
11/03/75	Influent	11/20/75	150.0	1.9 ± 50%	<2.0	–	–	Not Detectable
11/03/75	Effluent	11/20/75	120.0	2.2 ± 45%	<2.0	–	–	Not Detectable

Note: (1) The error expressed is the percentage relative to 2-Sigma counting error.

(2) The minimum detectable limit of gross Beta is 1.0 pCi/l.

(3) The minimum detectable limit of gross Alpha is 2.0 pCi/l.

(4) See Figure IV-1 for location of sample sites.

All measurements of gross beta radiation are much less than the 1,000pCi/l USPHS limit and no trend of change between influent and effluent is apparent. The only measurements of Sr-90 and Ra-226 occur at the influent sampling station on 2/11/75, and are both less than the USPHS limits of 10 pCi/l and 3 pCi/l, respectively. All measurements of gross alpha radioactivity are less than the minimum limit of detection and are less than the USPHS limit of 3 pCi/l for the more specific alpha emitter, Ra-226, indicating acceptable levels. Measurements of specific gamma radiation are all below the minimum limit of detection.

Microbe sampling - Results of water analysis for cytopathic (i.e., harmful to body cells) viruses and coliform bacteria are presented in Table IV-19. Microscopic examinations of cell cultures for cytophatic effects from concentrate of Druid Lake water samples are negative.

Measurements of total and fecal coliform bacteria indicate that these bacteria are essentially nondetectable.

Characterization Studies

Water quality and benthos survey - A survey of water temperature and dissolved oxygen (DO) at various depths was performed on 21 August 1975 to observe any existing thermal stratification. Thermal stratification is caused by the occurrence of different densities of surficial waters and deeper waters. Once stratification is initiated, mixing of deeper and surface waters becomes difficult and the density interface (thermocline) becomes stable. A state of stable stratification is characterized by stagnant water below the thermocline having low levels of DO and temperature, as well mixed water above the thermocline having dramatically higher levels of DO and temperature.

Druid Lake is a dammed natural depression and has depths of up to about 15 m. (50 feet). Under natural conditions, such a lake would probably become well stratified by late summer. However, this reservoir has an annual average flow of 112 cum/d (42.7 mgd) through it which provides a strong mixing influence.

Sampling stations of the water quality survey were located in the center of Druid Lake (labled as benthic sampling stations in Figure IV-2), at the deepest areas. Measurements of temperature and DO for each of the sampling stations is presented in Table IV-20. Water temperatures at all three sampling stations show little temperature change from surface to bottom waters. Stations D-A, D-B, and D-C have total changes of 1.5°C, 1.6°C, and 2.2°C, respectively. Measurements were made during morning, starting at D-A and finishing at D-C with a breeze starting in late morning. The time of sampling and breeze may explain the increased surface temperature and DO at station D-C. No abrupt change of temperature occurs with depth which indicates the absence of a thermocline. Concentrations of dissolved oxygen typically diminish gradually from surface to bottom

TABLE IV-19

VIRAL AND BACTERIAL ANALYTICAL RESULTS FROM EPA SAMPLING OF DRUID LAKE, BALTIMORE, MD. AND HIGHLAND RESERVOIR NO. 1, PITTSBURGH, PA.

DRUID LAKE(1)

Date Sample Collected	Virus Results (PFU)(3)	Coliform Bacteria (colonies/100 ml)	
		Total	Fecal
8/19/75	Negative	-	-
10/01/75	Negative	<0.00059	<0.00059
12/03/75	Negative	<0.00059	<0.00059
HIGHLAND RESERVOIR NO. 1(2)			
8/20/75	-	-	-
10/02/75	Negative	<0.00059	<0.00059
12/06/75	Negative	<0.00059	<0.00059

Note: (1) See Figure IV-2 for location of sampling site (D-2).

(2) See Figure V-2 for location of sampling site (H-4).

(3) PFU = Plaque Forming Unit

TABLE IV-28

TEMPERATURE-DISSOLVED OXYGEN WATER COLUMN PROFILES OF DRUID LAKE

Reservoir Depth (ft.)[3]	Sample Sites[1][2]					
	D-A		D-B		D-C	
	Temperature (°C)	Dissolved Oxygen (ppm)	Temperature (°C)	Dissolved Oxygen (ppm)	Temperature (°C)	Dissolved Oxygen (ppm)
0	17.4	6.7	17.6	6.3	18.2	7.5
5	17.0	5.9	17.2	5.9	17.8	6.3
10	16.6	5.6	16.7	5.4	17.0	5.4
15	16.3	5.3	16.3	5.2	16.7	5.2
20	16.1	5.3	16.5	5.1	16.4	5.1
25	16.2	5.2	16.5	5.0	16.3	5.0
30	16.7	5.1	16.3	5.0	16.1	4.9
35	16.0	4.9	16.2	5.0	16.1	4.9
40	15.9	4.9	16.1	4.9	16.1	4.9
45	–	–	16.1	4.9	16.0	4.9
50	–	–	16.0	4.8	16.0	4.9

Note: (1) All of these measurements were made during the morning of 21 August 1975.
(2) See Figure IV-2 for location of sample sites (which are included with the benthic sampling sites).
(3) One foot = 0.305 m.

with the exception of the top 1.5 m. (5 feet) at station D-C which shows a change of 1.2 ppm. Stations D-A, D-B, and D-C have total changes of 1.8 ppm, 1.5 ppm, and 2.6 ppm, respectively. No dramatic change of DO concentration occurs which indicates the absence of a thermocline.

Neither measurements of temperature nor dissolved oxygen provide evidence indicating that stratification existed in Druid Lake on 21 August 1975.

Part of the water quality and benthos survey included a qualitative survey of benthic organisms at the five sampling stations shown in Figure IV-2. Results of the benthos survey are presented in Table IV-21. Sample stations, D-A, D-B, and D-C are at the same locations as the stations of DO and temperature measurement discussed above. Two additional benthic sampling stations located at increasingly shallow depths provide information concerning the types of microorganisms of reservoir bottoms of different depths. All of the organisms listed in Table IV-22 except the Rotifera are algae which have settled to the bottom. Of the algae found on the reservoirs'bottom, all are diatoms except for two green algae, Ulothrix sp. and Zygnema sp., and a flagellated alga, Stephanodiscus sp. Only three of the algae (Phytoplankton) identified in the routine sampling program are also among the algae identified by the benthos survey. These three algae genera are the diatoms; Asterionella, Fragilaria, and Navicula.

The spatial location of the various forms of algae is probably not significant owing to variable water currents and floating properties of the algae which disperse them.

Dustfall sampling - The amount of airborne particulates settling on Druid Lake was measured from April, 1975 to January, 1976. Results of this sampling program are presented by sampling location on a unit basis in Table IV-22. Sampling stations are at opposite ends of the reservoir (Figure IV-2). Most of the measurements were invalid and are therefore not shown in the Table because of sampling problems. A typical dustfall value is about 2.5 g/sq.m. (22 lb/acre) per standard 30 day month. If this amount of solids is suspended in the entire volume of the reservoir (1.16 million cu.m. (306 million gal) during a seven day period (theoretical reservoir detention time) the result is a suspended solids concentration of 0.1 micrograms/liter. This concentration is an insignificant 0.1 percent of the typical influent or effluent suspended solids concentration of 100 micrograms/liter indicated by the routine sampling program (Table IV-6). Thus, by removing one source of potential suspended solids the dustfall sampling program supports the previously developed contention that most of the suspended solids in the reservoir are present owing to influent concentrations.

TABLE IV-21

DELINEATION OF BENTHIC MICRO-ORGANISMS INHABITING DRUID LAKE, BALTIMORE, MD.

Name of Organism	Benthic Sample Sites(1)				
	D-A	D-B	D-C	D-D	D-E
Diatoma sp.	X				
Pinnularia nobilis	X	X	X	X	
Rhopalodia gibba	X	X	X	X	X
Surirella sp.	X	X	X	X	
Synedra ulna	X	X	X	X	X
Cocconeis sp.				X	
Cymbella sp.					X
Navicula sp.		X			X
Fragilaria sp.	X	X			
Nitschia sigmoidea	X	X	X	X	X
Ulothrix sp.	X			X	
Cymatopleura solea	X				
Tabellaria fenestra	X			X	X
Stephanodiscus sp.		X	X		
Asterionella sp.		X	X		X
Zygnema sp.				X	
Cocconeis flex					X
Eunotia sp.					X
Rotifera			X		

Note: (1) See Figure IV-2 for location of sample sites.

TABLE IV-22

DUSTFALL SAMPLING RESULTS FOR
DRUID LAKE, BALTIMORE, MD.

Month of Collection	Dustfall Data (lb/acre)(1)(2)	
	Site DD-1	Site DD-2
April, 1975	-	-
May	-	-
June	15	-
July	23	3
August	23	22
September	-	20
October	-	20
November	-	-
December	-	-
January, 1976	-	-

Note: (1) See Figure IV-2 for location of sampling sites.

(2) 1 lb/acre = 112 mg/sq.m.

Examination of potential contamination by birds - Druid Lake is about 5 km (3 miles) from tidal waters of the Chesapeake Bay, a prime habitat of seagulls. Moreover, several solid waste disposal landfills exist in the Baltimore Metropolitan area which are used as foraging sites and serve as a source of food for seagulls. The birds can contaminate Druid Lake by defecation or deposition of contaminants including pathogens, by transporting the contaminants on their bodies from landfills used as feeding areas.

The results of the waterfowl siting program conducted by the Division of Water during the course of the overall water sampling program indicated that waterfowl (seagulls and ducks) were present on the lake 72 percent of the time. They were spotted during winter, as well as during the summer. The sighting breakdown was as follows:

Numbers of Waterfowl Sighted	Percent of Time
None	28%
1-10	33%
10-100	33%
Above 100	6%

In addition to the above mentioned program, a spot check was made by Engineering-Science, Inc. and the Baltimore Division of Water on 4 December 1975 as to the presence of seagulls on the lake and at selected landfills within the proximity of Druid Lake. Several seagulls were seen on the reservoir. No seagulls were sighted at the Monument Landfill which receives 25-35 metric tons (30-40 short tons) of dirt and bulk refuse per day. Thousands of seagulls were sighted at the Reedbird Landfill which receives about 140 metric tons (150 short tons) of bulk material per day and about 590 metric tons (650 short tons) of municipal waste per day.

Most of the wastes presently received by landfills in Baltimore City will be disposed of using a pyrolysis plant scheduled to go on-line in the immediate future. This plant will process wastes currently received by Reedbird Landfill and other landfills near Druid Lake. However, some solid waste facilities will still be operating within the range of Druid Lake. Consequently the potential of reservoir contamination by foraging seagulls will still exist.

The following is a list of number and proximity of solid wastes facilities to Druid Lake (as of approximately 1970)(Ref. IV-14):

Distance from Druid Lake miles (1 mile = 1.6 km)	Number of Solid Waste Facilities (cumulative)
1	0
2	0
3	1
4	2
5	4
10	11

Hydraulics of Druid Lake - The average volume of water stored in Druid Lake is approximately 1.16 million cu.m. (306 million gallons). The maximum storage capacity is 1.34 cu.m. (355 million gallons). At the average annual flow calculated during the study period (February 1975 - January 1976) of 112.3 cu.m./min. (42.7 mgd), the theoretical average hydraulic residence time becomes 7.2 days. The similarity in influent and effluent flows to and from the reservoir indicates that any additional water inputs or outputs (i.e., groundwater, evaporation, percolation, etc.) are either negligible, or tend to cancel out in the overall water budget for the reservoir. It should be noted that the actual residence times are probably less than the theoretical time even though the influent diffuser and effluent, multiple-port withdrawal structure are appropriately designed. The existing channel in the basin and the lack of baffling are responsible for some flow short-circuiting and a subsequent decrease in hydraulic residence times.

Summary of Data Evaluation

Routine Sampling Program

Most of the water quality parameters in the routine sampling program (Table IV-23) indicate some pattern of change during the sampling period; exceptions are apparent color, total hardness, ammonia, total coliforms, and fecal coliforms.

The following parameters showed general increases or decreases in concentration between the influent and effluent sampling locations:

General Increase	General Decrease
pH	Turbidity
Total Solids	Total Chlorine Residual
Copper	Free Chlorine Residual
Total Standard Plate Count	Nitrate

Temperature, dissolved solids, total hardness and phytoplankton showed both increases and decreases at different times during the study.

TABLE IV-13

PATTERNS OF WATER QUALITY CHANGE AND COMPLIANCE WITH WATER QUALITY STANDARDS
ROUTINE SAMPLING PROGRAM - DRUID LAKE

Water Quality Parameters	Changes in Concentration				Compliance w/Standards	
	Time-related Changes	Change Between Sampling Stations			U.S. Public Health Service Drinking Water Standards (IV.2)	
		Increased In Effluent	Decreased In Effluent	Mixed Patterns of Change	Required	Recommended
Temperature	Yes	No	No	Yes	—	—
pH	Yes	Yes	No	No	—	—
Apparent Color	No	No	No	No	Yes	—
Turbidity	Yes	No	Yes	No	Yes	—
Total Solids	Yes	Yes	No	No	—	—
Dissolved Solids	Yes	No	No	Yes	—	Yes
Suspended Solids	Yes(1)	No	No	No	—	—
Total Alkalinity	Yes	No	No	No	—	—
Total Hardness	No	No	No	Yes	—	—
Total Chlorine	Yes	No	Yes	No	—	—
Residual Chlorine	Yes	No	Yes	No	—	—
Copper	Yes	Yes	No	No	—	Yes
Lead	Yes	No	No	No	Yes	—
Ammonia	No	No	No	No	—	—
Nitrate	Yes	No	Yes	No	—	Yes
Total Phosphate	Yes	No	No	No	—	—
Soluble Ortho-phosphate	Yes	No	No	No	—	—
Total Coliforms	No	No	No	No	Yes	—
Fecal Coliforms	No	No	No	No	—	—
Total Standard Plate Count	Yes(2)	Yes	No	No	—	—
Phytoplankton	Yes	No	No	Yes	—	—

Note: (1) Influent only.
(2) Effluent only.

The 1962 U.S. Public Health Service Drinking Water Standards were met in all cases. However, levels of three parameters (temperature, ammonia, and soluble orthophosphate) do not meet other criteria (see previous discussion of sampling results) of desirable water quality on occasion; the levels observed do not appear to be of concern.

Special Sampling Program

Total organic carbon (TOC) - Both influent and effluent concentrations of TOC generally follow the same yearly trend although effluent values are typically lower than influent values.

No limit of TOC has been set by the USPHS, however, all concentrations of TOC are generally low.

Trace metals - All of the metals analyzed were within the limits of the 1962 USPHS standards. Most of the data could not be analyzed because most of the observed concentrations were equal to or below the analytical limit of detection. Mercury is not included in the USPHS standards, but observed concentrations were less than generally accepted safe concentrations.

Of the ten trace metals measured only manganese concentrations show a pattern of change during the sampling time period. None of the trace metals except iron change in concentration between sampling stations. Iron values show a slight decrease from influent to effluent.

Radiochemical isotopes - The following parameters were measured at influent and effluent locations of Druid Lake as indicators of radioactive contaminants; gross beta particles, gross alpha particles, stronium-90 (Sr-90), radium-226 (Ra-226), and specific gamma radiation.

None of the results from analysis of the parameters indicate patterns of change during the sampling period or change in value between sampling stations.

The USPHS has set drinking water standards for gross beta particles, Sr-90, and Ra-226. All measurements of these three parameters are less than the USPHS standards. Measurements of gross alpha particles and specific gamma radiation are less than generally accepted criteria.

Microbe sampling - Results of Druid Lake analysis for cytopathic viruses were negative. Water analysis for total and fecal coliform bacteria indicated that these bacteria were essentially nondetectable.

Characterization Studies

Water quality and benthos survey - on 21 August 1975 measurements of temperature and dissolved oxygen (DO) were performed at regular intervals of depth, at three locations in Druid Lake. Results of this sampling indicate little change in temperature or DO from surface to bottom. The slight amount of change that does occur shows a typical rapid decrease in temperature and DO values near the surface with a much slower decrease near the bottom. Neither measurements of temperature nor DO provide evidence indicating that stratification existed in Druid Lake.

A qualitative survey of benthic microorganisms was performed on 25 August at five locations in Druid Lake. The 19 organisms identified were rotifers and 18 species of algae. The algae included 15 species of diatoms, two species of green algae, and one flagellated algal species. Most of these algae had probably settled to the bottom from upper depths.

Dustfall sampling - Results from measuring dustfall at two locations on Druid Lake indicate a typical value of about 2.5 g/sq.m. (22 lb/acre) per month. If dustfall were to account for the suspended solids concentration in the reservoir then the concentration would be about 0.10 micrograms/liter instead of the typical suspended solids concentration of 100 micrograms/liter indicated by results of the routine sampling program.

Examination of potential contamination by birds - A spot check on the presence of seagulls at Druid Lake and two nearby landfills which could be used by foraging seagulls as a feeding area resulted in the observation of several seagulls on Druid Lake, no seagulls at one landfill which only receives dirt and bulk refuse, and thousands of seagulls at a landfill which received a great amount of municipal wastes. There are four solid wastes facilities within 8 km (5 mi) of Druid Lake and 11 facilities within a 16 km (10 mi) range of the reservoir. Landfills which presently exist near Druid Lake will be phased out as a new pyrolysis plant comes on-line. The existence of other solid wastes facilities makes the reservoir susceptible to contamination by foraging seagulls. Foraging has been reported at distances up to 30 km.

Hydraulics of Druid Lake - The calculated annual average flow of water through Druid Lake was 112.3 cu.m./min. (42.7 mgd) for both influent and effluent during the study period (Feb. 1975-Jan. 1976). The theoretical detention time was 7.2 days.

ALTERNATIVE WATER QUALITY CONTROL MEASURES

Introduction

A clearly desirable objective of water system operations is the maintenance of water quality throughout the system from the treatment plant to the consumer's tap. However, storage of water to meet peak consumer demands is usually necessary, and this portion of the system is usually where the greatest potential for water quality degradation occurs.

Previously discussed possible sources of causes of water quality degradation in Druid Lake include:

- airborne particulates
- surface runoff
- groundwater
- unauthorized human contact
- birds
- weather
- biological process in the reservoir

The measures which may be taken to minimize or eliminate the potential degradation in reservoir water quality may be put into one of two basic categories:

(1) Preventive - measures to prevent contamination or development of an undesirable condition, and

(2) Corrective - measures to correct such conditions after they have occurred.

Both types of control measures may involve construction of facilities or the use of operation and maintenance procedures. In general however, the majority of the possible preventive measures will make use of some large capital investment, whereas most corrective measures may be classified as operational changes and/or modified maintenance procedures.

Preventive measures are to be preferred in most cases. Hazardous and other undesirable conditions may occur at any time, and once such a condition has occurred water quality remedial procedures depend on the continuous integrity of the corrective system. For example, if protection of the system from bacterial contamination is to be accomplished with chlorination, there must be standby chlorinators maintained in an operable condition, adequate supplies of chlorine, failure alarms, monitoring devices, acceptable contact time, etc. A system which prevents bacterial contamination of the reservoir in the first place would usually be considered preferable.

Prevention of contamination is also desirable from the standpoint of protection against presently unidentified contaminants. In almost all cases experience and increasing analytical capability has added to the lists of hazardous and undesirable conditions or constituents in potable water. Presumably this trend will continue. Control measures designed to mitigate specific conditions may not affect yet-to-be-identified adverse conditions. However, measures designed to prevent the entry of most contaminants into the water system have a better chance of meeting future system requirements.

Preventive Control Measures

There are several preventive control measures which can protect the Druid Lake water quality to some degree from one or more of the above mentioned sources of water quality degradation. Moreover, some of these preventive measures may be combined to form additional alternatives which can afford increased protection to the finished waters. These measures include covering the reservoir, bottom lining of the reservoir, proper grading and design of the reservoir site to prevent the entry of surface runoff, and establishment of proper security measures such as physical barriers and patrols.

Reservoir Covers

A reservoir cover would essentially eliminate airborne particulates and birds from contact with the water. It would reduce the possibility of contact by unauthorized people as well as the effects of weather. Algal growths are minimized because of the elimination of sunlight (new algae growth would be eliminated and regrowth would be prevented). There are two types of covers to be considered for Druid Lake: a rigid cover and a floating cover.

Rigid cover - The relatively large size of the reservoir (20 ha., or 50 acres) precludes consideration of all but a plywood roof and a precast concrete roof.

The plywood roof would be constructed of plywood sheets supported on glue-laminated purlins and girders which would be supported on precast columns and a peripheral wall. Because of the moist environment, all wood components of the cover would have to be treated with a wood preservative such as pentachlorophenyl or creosote. There is no satisfactory way to prevent condensate from the underside of the roof and supporting members from dripping into the water. Thus the wood preservative chemicals will enter the water and may cause taste and odor problems and may provide a nutrient source for bacterial growth. For these reasons the U.S. Environmental Protection Agency will not approve the use of creosote as a preservative for wood reservoir covers (Ref. IV-16). The loss of wood preservative results in additional periodic maintenance costs over the 25 to 50-year expected life of the cover. Because of the taste and odor problem and additional costs, the plywood roof was eliminated from further consideration as a viable preventive alternative.

A concrete cover could consist of precast reinforced concrete slabs supported by integral concrete beams which rest upon interior reinforced concrete columns and a perimeter shear wall. Such a cover provides a roof and side walls which minimize contact with the ambient environment and is effective in excluding contaminants from the reservoir when properly maintained and operated.

Several common operation and maintenance procedures include: (1) ventilation openings in the cover must be periodically cleaned of debris; (2) manholes must be free of obstructions; (3) water tight seals of the roof must be maintained; and (4) water which might collect on the roof must be drained. A concrete cover is rigid which means that the cover will remain in place if the reservoir must be drained for inspection and/or repair work on the bottom.

The environmental impact of a concrete cover over Druid Lake is principally concerned with detracting from the visual and aesthetic nature of the nearby Druid Park area. The open water of the reservoir is probably more attractive than an expanse of concrete. However, the cover could be designed to provide a suitable surface for uses such as tennis courts, automobile parking, or it may even be landscaped to fit into the park.

The estimated construction cost of a concrete cover for Druid Lake is about $17 million based on a preliminary design that would support uses such as automobile parking and tennis courts. This figure should be added to other costs (legal, administrative and engineering, etc. about 25%) and an allowance for contingencies (15%) for a preliminary estimate of around $24 million total cost.

This cost is considered conservative (within the assumptions made) and it might be reduced somewhat by careful analysis of design alternatives. On the other hand, other desired uses such as extensive landscaping with soil or sod might result in some increase in cost.

Flexible floating cover - A flexible floating cover consists of an elastomeric sheet stretched over the reservoir's water, supported by foam floats, attached to a peripheral concrete foundation. The cover rises and falls with the water level and is sloped from the center to the perimeter causing rain water to drain and collect near the outside where it is pumped out. When properly maintained and operated, the cover protects reservoir water quality as does the concrete cover.

While operation of Druid Lake with a floating cover would be similar to operation under a rigid cover, the costs of operation and maintenance would probably be less owing to the simplicity of the floating cover system. However, inspection and repair of the bottom including sediment removal would be more difficult with a floating cover. Work must be performed underwater because the roof would fall to the bottom if the reservoir were drained.

The principal components of a floating cover for Druid Lake are: (1) an elastomeric material and foam floats; (2) anchorage foundation around the reservoir perimeter; and (3) a pump/siphon system to remove surface water. While several types of elastomeric materials are available for use as covers, the material considered best for Druid Lake is composed of chlorosulfonated polyethylene (Hypalon, DuPont), a synthetic rubber, reinforced with nylon. The useful life of a cover made of this material is 20 to 40 years.

Estimated construction costs (1976) for installation of the floating cover system on Druid Lake ranges from about $2.2 million to $3.8 million, with the higher cost probably being more realistic. The total cost (including other costs and contingency allowance) would be about $5 million.

The principal environmental effect of installing a floating cover on Druid Lake is that the reservoir would be visually unattractive as in the case of a concrete cover. Unlike a concrete cover, however, a floating cover provides no other use than protecting the water of Druid Lake.

Reservoir Bottom Lining

An impermeable lining on the bottom of a finished water reservoir will prevent water leakage from the basin and will also prevent the infiltration of groundwater and associated dissolved solids into the reservoir. Several distinct types of liners exist (Ref. IV-17): concrete, pneumatically applied mortar, e.g., gunite, hydraulic asphalt concrete, prefabricated asphalt panels, plastic sheeting, and synthetic rubber.

Only linings made of plastic or synthetic rubber are considered to be feasible for Druid Lake because of the high cost of the other types of liners and the large surface area of the reservoir to be lined. Installation of plastic or synthetic rubber linings essentially consists of preparing the bottom, laying the lining material, and anchoring the material. Of the materials considered for Druid Lake, polyvinyl chloride (PVC) is more susceptible to deterioration by ozone and ultraviolet exposure than other membranes (Ref. IV-18) which means that this material must be covered above the lowest normal water level. Maintenance of an installed lining is minimal. Periodic removal of accumulated sediments may be required.

The types of plastic and synthetic rubber linings considered for Druid Lake are the following: plastic-polyvinyl chloride (PVC), ethylene propylenediene monmer (EPDM), and chlorinated polyethylene (CPE), synthetic rubber-butyl rubber, and chlorosulfonated polyethylene (Hypalon, DuPont). Manufacturers' minimum projections of life expectancy are about 40 years for all of these liners when properly installed and maintained. Actual use of these materials has been met with varying amounts of success and no particular one will be recommended.

A survey of installation costs for lining Druid Lake indicates the following prices:

Hypalon (nylon reinforced) = $ 976,000 - $1,677,000

EPDM (nylon reinforced) = $1,367,000 - $2,169,000

Butyl rubber = $ 976,000

CPE (nylon reinforced) = $ 976,000 - $1,085,000

PVC (nylon reinforced) = $ 759,000

The presence of a membrane liner in Druid Lake may make the reservoir less attractive because of a synthetic shoreline being exposed rather than a natural appearing shoreline.

Surface Runoff Diversion

Erosion products from surrounding paved and unpaved areas of a finished water reservoir have the potential of being carried by rain or snowmelt surface runoff into the reservoir. Accumulation of contaminants on paved areas between rainstorms causes the first flush of rain runoff from a storm to possess high concentrations of pollutants. Surface runoff may increase reservoir concentrations of phosphorus, nitrogen, organics, suspended solids, zinc, and lead. During winter, surface runoff of deicing compounds may increase concentrations of dissolved solids from the presence of sodium chloride and/or calcium chloride.

Surface runoff of erosion products does not present a significant source of contaminants to Druid Lake. The reservoir is surrounded by a 0.6 m (2 ft) high parapet wall. This wall plus the adequate storm drainage system of the area practically eliminates the possibility of surface runoff contamination.

Security Establishment and Maintenance

To preserve the high quality of water in a finished water reservoir, people must not be allowed to swim or otherwise have contact with the water or to throw objects into the water. The preclusion of these acts will help prevent introduction of pathogenic organisms by swimmers and a variety of thrown items including dead animals, drugs, and toxic substances (Ref. IV-19). Reservoir security may be established and maintained by the presence of a physical barrier such as a perimeter fence and existence of a security patrol.

Druid Lake is protected from public access by a 1.8 m (6 ft) high fence, setback approximately 15 m (50 ft) from the water's edge. Security surveillance of the reservoir is accomplished by routine periodic checks by police who patrol the perimeter in vehicles. In addition to police surveillance, employees of the Water Department provide regular surveillance during their general daily travel, especially those employees who travel to and from the chlorination station during the course of the week. Security violations have occurred only occasionally.

This present security program is believed adequate, and consequently no further improvements and their associated costs will not be considered for Druid Lake for the purposes of this report.

Possible security improvements include the following: (1) increase the height of the perimeter fence and/or the distance of fence setback (it has been recommended (Ref. IV-20) that the product of fence height and setback should be at least 600 feet); (2) initiate a more intense, structural surveillance system; and (3) establish a formal emergency plan for quick isolation of the reservoir from the distribution system if the water is thought to be dangerous.

Corrective Control Measures

The various measures available to correct and/or improve water quality conditions in Druid Lake that occur as a result of one or more of the previously discussed sources of degradation primarily involve post-reservoir treatment, operational changes, modified maintenance, and a proper monitoring program. The nature and extent of these corrective measures for Druid Lake will be based on the results of the extensive sampling and characterization programs that were discussed earlier in this chapter. That is, only the measures that correct identified problems will be evaluated.

The sampling results suggest that effluent residual chlorine concentrations and the associated contact times to assure adequate disinfection and pathogen deactivation need to be considered in terms of post-reservoir treatment. Also, regular addition of copper sulfate is necessary to prevent the growth of algae and other microorganisms which are among the most frequent causes of taste and odor. Programs to control growth of shore plants and to reduce the potential of contamination by waterfowl should be taken into consideration. The existing water quality monitoring program as currently practiced at Druid Lake appears to be adequate relative to insuring that the water will meet the 1962 USPHS Standards. Additional monitoring may be warranted, but will not be pursued further in this report.

The following discussion will summarize the necessary corrective measures required at Druid Lake to maintain the quality of the water delivered to the consumer. Specific water quality parameters affected include; bacteria (e.g., coliforms), viruses, phytoplankton, organic compounds (including constituents-carbon, nitrogen, and phosphorus compounds) copper, chlorine/chlorine compounds, turbidity, color, solids, taste and odor. The measures will involve continuation of existing adequate operational procedures, as well as the implementation of necessary improvements to achieve the desired water quality.

Chlorine Disinfection

Chlorine disinfection is presently used in operation of Druid Lake to control pathogenic organisms. Both influent and effluent water undergo chlorination. Influent chlorination is about three times greater than effluent chlorination. A concentration of 3-5 ppm during summer and 1-3 ppm during winter is maintained in influent water. Post-reservoir chlorination insures that 1 ppm chlorine residual is maintained in effluent water. To assure that there is effective post-reservoir disinfection an additional two-hour reaction time is proposed to accompany the existing post-chlorination facilities. This reaction time will assure effective disinfection without water reaching the consumer with an undesirable concentration of residual chlorine which may be objectionable due to the presence of tastes and odors.

A contact basin volume of four million gallons is required to effect a two hour reaction time for postchlorinated Druid Lake effluent. The proposed volume will consist of a rectangular earthen basin which will be lined with an impermeable, butyl neoprene bottom liner and covered with a floating nylon-reinforced, synthetic rubber cover. In this manner, the chlorine contact basin will be effectively isolated from potential sources of contamination while it is being used for disinfection purposes. A basin with an average depth of ten feet will need an area of approximately 1.2 acres. It could be located adjacent to the effluent end of the Lake so as to minimize the need to rearrange existing piping. Water will flow by gravity from Druid Lake to the contact basin. Existing reservoir prechlorination and postchlorination facilities will be continued to be used. Postchlorination facilities will be rearranged so as to inject chlorine prior to the two-hour contact basin for proper mixing. The same amounts of chlorine will be applied in this proposed scheme as are being applied now.

Chlorination facilities for Druid Lake are presently centralized at one station. Influent water is chlorinated by one 2.7 metric ton (3 ton) chlorination unit with one additional identical unit on standby. Chlorine feed rate is set manually based on the previous 24 hour flow and results from the system water quality monitoring program (see Chapter II). A total of ten 910 kg (1 ton) cylinders are at the station, four of which are standby cylinders.

The capital costs for the construction of the chlorine contact basin including bottom lining, floating cover, additional piping, other miscellaneous costs, and contingencies are approximately $300,000.

Prechlorination and postchlorination required a total (during 1975) of about 84,000 kg (187 tons) and 29,000 kg (63 tons) of chlorine, respectively. Based on chlorine prices (1975) of $0.23 kg ($210/ton), January to June, and $0.28/kg ($250/ton), June to December, total annual costs of chlorine were:

(1) prechlorination = $43,600; and

(2) postchlorination = $14,700

Total labor requirements for chlorination of Druid Lake water were the following (1975-76):

(1) general servicing = 6 hr/wk;
(2) maintenance = 4 hr/wk; and
(3) chlorine cylinder transport = 3 hr/wk

Total annual labor costs are about $3,200/yr.

Total annual labor costs of chlorination for Druid Lake are approximately $61,500/yr.

Results from the routine sampling program of this study indicate that residual chlorine concentration drops to near zero values in the reservoir effluent (before postchlorination) which allows increased levels of bacteria. Sufficient chlorine residual should exist in the reservoir (1-2 ppm) to prevent bacterial growth. Closer synchronization of chlorination with the water quality monitoring program may help facilitate maintenance of adequate chlorine residual in the reservoir.

Copper Sulfate Application

Effective control of algae growth exists with the present program of periodic copper sulfate addition at Druid Lake. Periodic applications of copper sulfate are accomplished by dragging bags of copper sulfate crystals behind a boat and by hand application from a row boat to the water's surface, particularly near the shoreline. During 1975, six applications of copper sulfate were made of 544 kg (1,200 lb) each on 9 April, 19 May, 20 June, 21 July, 12 August, and 15 October. The cost of copper sulfate alone was a total of $2,500/yr at $0.77/kg ($700/ton). Total annual labor costs are about $2,000/yr. Total annual chemical and labor costs for Druid Lake are about $4,500/yr.

Results from the routine sampling program of this study indicate that algae populations in Druid Lake are insignificant. Copper concentrations are also insignificant.

Shore Plant Growth Control

The present program being practiced at Druid Lake effectively controls weeds growing among the rock rip-rap along the banks of Druid Lake by two deweeding operations per year during summer-fall as needed. For each operation, deweeding entails two crews of six men each working for one week at a total cost of $4,200/yr (1975).

Bird Contaminant Control

The potential of introducing contaminants to the water of Druid Lake by resting birds has been discussed earlier in this chapter. In operation of Druid Lake, no particular effort is made to discourage the presence of birds on the reservoir. Installation of deterents such as water sprays, wires, ultrasonic devices, and others should be considered (Ref. IV-21). The costs for such control systems is not readily available and will not be included in the foregoing analysis. If, however, the comparison of preventive alternatives versus corrective alternatives reveals costs that are relatively competitive, the costs of bird control programs should be included to complete the cost-effectiveness analysis.

Summary of Corrective Measures

In order to maintain a high quality potable water to be delivered to the consumers the following costs will be incurred by continued operation of an open reservoir:

Control Measure	O&M ($/yr)	Capital Cost ($)
Chlorination/Disinfection	$61,500	$300,000
Copper Sulfate Addition	4,500	-
Shore Plant Control	4,200	-
Bird Contaminant Control	-	-
Totals	$70,200/yr	$300,000

Alternatives Trade-off Assessment

The various alternatives available for the maintenance of a high quality potable water supply for the City of Baltimore vis-a-vis Druid Lake involve measures to prevent contamination or development of an undesirable condition in the reservoir, and measures to correct such conditions after they have occurred. In particular, the results of the water sampling program detailed in this report were used as a basis to develop a preferred open reservoir management alternative comprised of corrective measures which would mitigate specific water quality problems. It was assumed that alternatives comprised of preventive control measures would protect Druid Lake from the possible sources or causes of the water quality degradation that were identified. As was previously discussed, water quality problems and degradation were defined by comparing the results of the sampling program with the 1962 USPHS Drinking Water Standards and other recognized water quality standards. The 1962 USPHS Standards, as well as other recommended drinking water standards, however, were not violated during the sampling period. Consequently, the evaluation of alternatives will focus on either the prevention or correction of potential water quality problems that could occur in the present system.

The inherent risk in encountering water quality problems in the open Druid Lake reservoir has been translated into a set of general control criteria for the overall management of an open reservoir system. Examples are preferred post-reservoir disinfection reaction times, recommended chlorine residual concentrations in the distribution system, and control of roosting waterfowl which may be disease carriers. The total costs associated with the adoption of the preferred open reservoir management alternative and the corresponding degree of mitigation of potential water quality problems and undesirable water quality conditions must be weighed against the various costs associated with covering Druid Lake and its corresponding impacts on water quality.

Total costs are defined as both the capital and the annual operation and maintenance costs associated with an alternative. Total costs may be expressed as the average annual equivalent cost over a 30 year period so as to represent all costs on an equivalent basis. In doing so, capital costs are amortized at a discount rate of six percent for the purposes of this analysis. Additionally, annual O&M costs are inflated at a six percent rate over the designated 30 year period, and then averaged.

The total costs of the aforementioned preferred open reservoir management alternative amount to an annual average equivalent cost of $207,000 per year. This is the sum of costs incurred by corrective measures. This comprised of an amortized capital cost of $22,000/yr and an average O&M cost of $185,000/yr considering inflation. Based on the water quality sampling program results, the control measures associated with this alternative will provide for the attainment of the 1962 USPHS Drinking Water Standard, as well as a proper postchlorination reaction time and other preferred operational procedures that will lessen the risk of potential water quality contamination. An unquantified additional expense would be incurred to ensure that the potential transmission of disease carried by roosting waterfowl was eliminated. This expense is not believed to be large relative to the stated total cost. Potential unidentified contaminants (e.g., asbestos and chloroform) may not be removed or reduced below harmful levels, however. In many cases, the long-term harmful levels of some of these contaminants have not been defined, and consequently it is difficult to judge the associated impacts. Moreover, although contaminants resulting from airborne entry, violation of reservoir security, and the loss of chlorine residual in the reserovir and the resultant growth of aquatic organisms with the potential for buildup of toxic organic compounds may be introduced, they were not specifically identified in this study. The costs (or, negative benefits) can not, therefore, be quantified for a complete trade-off assessment

An alternative incorporating the emplacement of a concrete cover on Druid Lake would incur an amortized capital cost of $1,744,000 per year. The average annual O&M costs cannot be estimated; however, they are expected to be less than the existing O&M costs experienced by the open system. A cover would considerably reduce the risks of encountering potential water quality problems below those that exist for an open reservoir. Experience has been that these contamination risks have not manifested in an instance of water quality degradation or imputable condition. Therefore, the question to be considered is whether the reduction of these risks will result in a benefit, and whether this benefit will offset the added costs of installing a reservoir cover in place of maintaining a properly managed open reservoir.

The emplacement of a floating cover over Druid Lake would result in an amortized capital cost of $361,000 per year. If, in addition, the reservoir was to be lined with a bottom, impermeable liner, amortized capital costs would increase to approximately $454,000 per year. Again O&M costs are not detailed, but if a cover (and liner) was to be installed, then the O&M costs of algae and shore plant control associated with an open reservoir would be eliminated and chlorination costs would be reduced. However, it is important to note that covered reservoir O&M costs would not be insignificant to the economic analysis of this alternative; hence total annual costs are expected to be greater than the amortized costs. Chlorination would still be required. In fact, the O&M costs of a floating covered reservoir would probably be greater than those of a concrete (rigid) cover reservoir due to additional maintenance costs. Also, the benefits afforded by a floating cover would not include the potential of using the cover for secondary functions such as automobile parking, tennis courts, additional park land, etc. (i.e., the added benefits of a rigid concrete cover). As with the concrete cover alternative, the confidence to maintain a continuous high quality, potable water is greater with the floating cover than with the preferred management and operation of an open reservoir. However, within the perspective of the prevention of potential, undetected water quality problems, the difference in costs between a floating cover alternative and the open reservoir alternative does not appear to be balanced by a commensurate increase in benefits attributed to the former. Ultimately, these benefits need to be quantified before the final decision is made.

CHAPTER IV

REFERENCES

IV-1 "Letter to Mr. Daniel Synder, Acting Regional Administrator, U.S. Environmental Protection Agency, Region III, from City of Baltimore Mayor William Schaeffer - EPA Survey of the Baltimore Water System," 23 July 1973.

IV-2 "Letter to City of Baltimore Mayor William Schaeffer from Mr. Edward Furia, Regional Administrator, U.S. Environmental Protection Agency, Region III," Findings and Recommendations of EPA, Survey of the Baltimore Water System, 11 July 1972.

IV-3 The Story of Baltimore's Water Supply, City of Baltimore, Department of Public Works, Bureau of Consumer Services, 1970.

IV-4 Personal communication, Jerry A. Valcik, Chief, Water Quality Section, Department of Public Works, Bureau of Utility Operations, City of Baltimore, Md.

IV-5 Standard Methods for the Examination of Water and Wastewater, 13th edition, American Public Health Association, Washington, D.C., 1971.

IV-6 "Use of Membrane Filters to Facilitate the Recovery of Virus from Aqueous Suspensions," Metcalf, T.G., Applied Microbiol. 9:376.

IV-7 The Large-Volume-Sampler (LVS) for Bacteriological Examination of Water, Ericksen, T.H., U.S. Environmental Protection Agency Health Effects Research Laboratory, Cincinnati, Ohio.

IV-8 "National Interim Primary Drinking Water Regulations," Federal Register, Part IV: Environmental Protection Agency, 24 December 1975.

IV-9 Non-parametric Statistics for the Behavorial Sciences, Seigel, Sidney, McGraw Hill, New York, 1956.

IV-10 Water Quality Criteria, California State Water Resources Control Board, 2nd edition, 1963.

IV-11 Wastewater Management by Disposal on the Land, Cold Regions Research and Engineering Laboratory, 1972.

IV-12 Monthly Composite Atmospheric Analyses, File Records, Baltimore Health Department, Air Pollution, 1976.

IV-13 *Algae Control in Water Supply Reservoirs*, Illinois Institute for Environmental Quality, 1973.

IV-14 *Baltimore City Solid Waste Management Plan*, Review Draft for the Baltimore Regional Planning Council, Roy F. Weston, Inc.

IV-15 "Covering Open Distribution Reservoirs," Chin, A.G., *Journal American Water Works Association*, Vol. 63, No. 12,(December 1971).

IV-16 "The Floating Cover: Best Way to Cover a Finished-Water Reservoir?", Dallaire, Gene, *Journal, Civil Engineering-American Society of Civil Engineers*, June 1975.

IV-17 "Reservoir Linings," Harem, F.E., Bellman, E.D., and J.E. Worth, *Journal American Water Works Association*, Vol. 68, No. 5, May 1976.

IV-18 "Selecting Membrane Pond Liners," Lee, Jack, *Pollution Engineering*, Vol. 6, No. 1, January 1974.

IV-19 *Health Aspects of Uncovered Reservoirs*, Fluntze, James C., Water Supply and Waste Section, Washington State Department of Social and Health Services, unpublished report.

IV-20 *Draft Environmental Impact Statement of Proposed Amendments to State Board of Health Rules and Regulations Regarding Public Water Supplies - WAC 248-54 - The Amendments Relate to Potable Water Distribution Reservoirs*, Office of Environmental Health Programs, Washington State Department of Social and Health Services, April 1975.

IV-21 *Protection of Open Reservoirs Against Birds*, Emigh, Frank D., Paper presented at the Pacific Northwest Section Meeting, Seattle, Washingon, May 1962.

CHAPTER V

HIGHLAND RESERVOIR NO. 1, PITTSBURGH: A CASE STUDY

INTRODUCTION

Highland Reservoir No. 1 was selected as a case study because, like Druid Lake (Chapter IV of this report) Highland is also typical of old, large, uncovered reservoirs located in an intensely developed, industrial city. For several years the City of Pittsburgh (Pennsylvania) has considered the emplacement of a cover on Highland Reservoir but the costs were considered too high to act without demonstrated need. Furthermore, Highland Reservoir is located within a park where certain types of covers could be be considered aesthetically objectionable.

Consumers have experienced sporadic taste and odor problems because of the occasional presence of biological growths and organic debris in water from Highland Reservoir No. 1. However, consideration of cover installation on the reservoir is primarily based upon potential problems rather than existing problems.

As in the selection of Druid Lake, a practical reason for selecting Highland Reservoir was that the Pittsburgh Department of Water was willing to provide both personnel and equipment for a water sampling and analysis program. In addition, information concerning water quality monitoring, water flows, and general operation and maintenance were also provided.

PHYSICAL CHARACTERIZATION OF HIGHLAND RESERVOIR NO. 1

Physical Attributes

Highland Reservoir No. 1 is located in the northeast portion of metropolitan Pittsburgh. The reservoir is a part of Highland Park, a large public park containing a zoo, swimming pool, and other recreational facilities. The reservoir serves a residential population of 180,000 people and provides water required by mecantile and manufacturing interests.

Highland Reservoir is an entirely artificial water body constructed in 1879 as two distinct basins. The partition separating the two basins was subsequently demolished so that the total surface area of the reservoir is about 8 ha. (21 acres). An average depth of about 6 m. (20 feet) to the earthen bottom is present in the reservoir. The capacity of the reservoir is approximately 500,000 cu.m. (130 million gallons). Treated water is pumped to the reservoir from a 50 million gallon clear well at the

Pittsburgh water treatment plant. The water enters Highland Reservoir through a chamber which disperses the flow into two individual streams (one into each of the two formerly separate basins (Figure V-1). The average daily flow through the reservoir during 1975 was about 110 thousand cu.m./day (30 million gallons per day), resulting in theoretical residence time of 4.5 days. Water is withdrawn from four effluent vaults located in widely separated areas (Figure V-1).

Highland Reservoir is surrounded by a fence about 1.2 m. (4 feet) high which prevents people from falling into the water. The lower portion of the fence is a low parapet wall designed to minimize surface drainage into the reservoir. Signs describing the use of the water and warnings against contamination are posted around the perimeter of the reservoir. A limited access, paved road also exists around the perimeter which is extensively used by walkers and joggers.

During warmer periods of the year thick algae mats grow in the shallow portions of the basin. When an algacide is applied or when colder weather occurs in autumn, the algae dies. Consequently, the mat of dead algae breaks away from these areas and becomes suspended in the body of the reservoir where it may be withdrawn in effluent water.

Birds proliferate the trees in the park surrounding the reservoir, but do not use the reservoir itself as a roosting area.

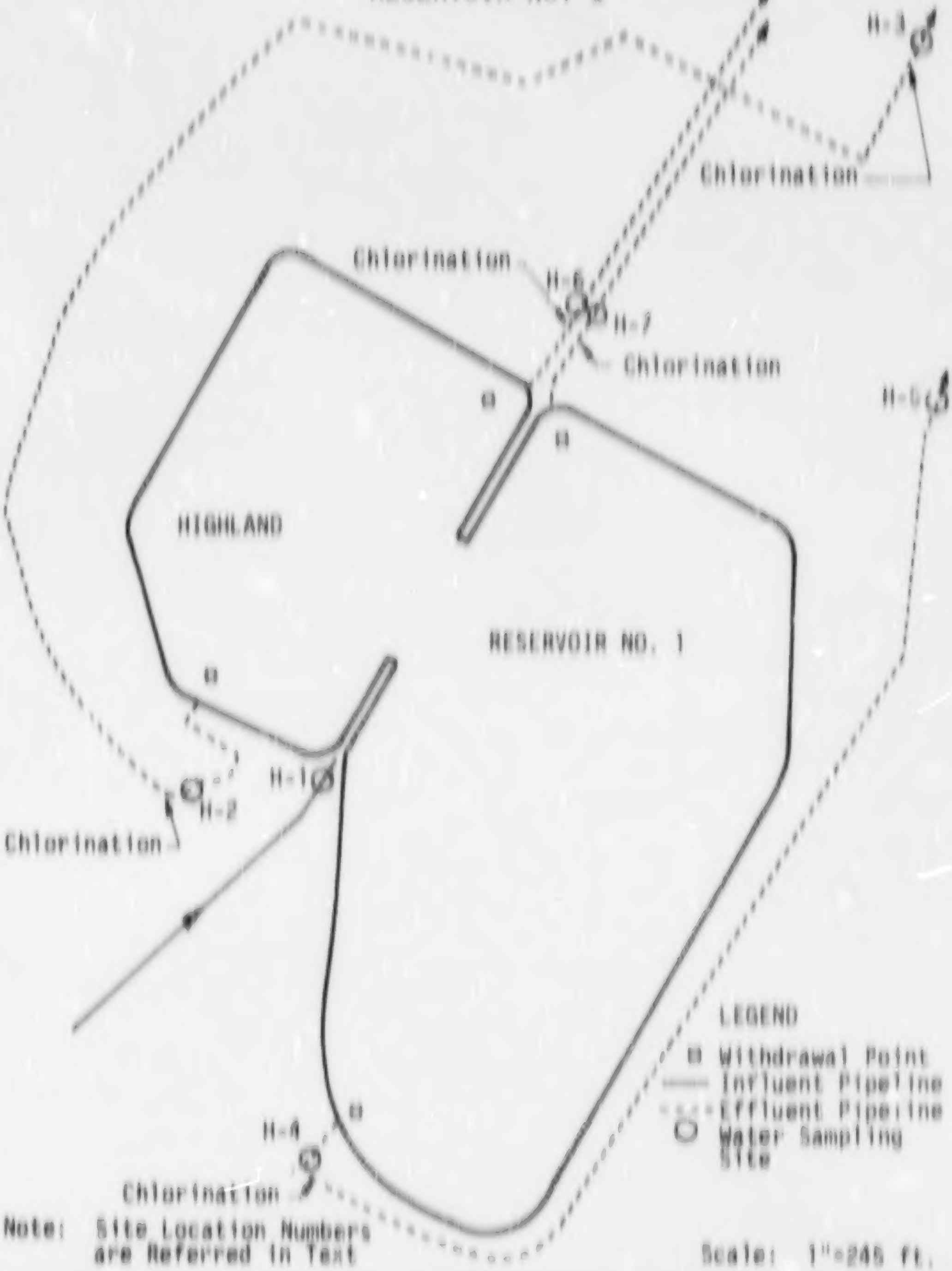
Existing Water Quality Monitoring Program

Routine monitoring of water quality in Highland Reservoir No. 1 consists of taking grab samples from three of the four effluent pipelines. Sampling is performed once each day from withdrawal lines located at opposite sides of the reservoir (Figure V-1): effluent lines with water sampling sites; H-2, and either H-6 or H-7). Water from the third effluent line is sampled once every two days (Figure V-1): effluent line with water sampling site H-4). Water samples collected from these locations are analysed for total coliforms, total bacteria (total standard plate count), color, odor, turbidity, hardness, chlorides, iron, manganese, residual chlorine, pH, and alkalinity. If the count of the total coliform bacteria is high, then the reservoir is immediately tested for the presence of fecal coliform bacteria. A 24-hour time lag usually exists between water sampling and bacteria analytical results. Chlorine residual is also monitored at several other locations throughout the distribution system, five days per week. The quality of influent water to Highland Reservoir is monitored twoce per day by sampling the discharge from a large closed clear well which precedes the reservoir and which follows the Pittsburgh Water Treatment Plant. The parameters measured are those necessary to comply with the U.S. Public Health Service Drinking Water Standards of 1962. An approximate 10 - 12 hr. lag exists from the time water leaves the treatment plant until it reaches Highland Reservoir.

Operation and Maintenance

Operation and maintenance procedures at Highland Reservoir No. 1 are implemented to insure continuous high water quality of effluent water and

FIGURE V-1 LOCATION OF WATER SAMPLING SITES FOR HIGHLAND RESERVOIR NO. 1


H-3
Chlorination
Chlorination
H-6
H-7
Chlorination
H-5
HIGHLAND
RESERVOIR NO. 1
H-1
H-2
Chlorination
LEGEND
▫ Withdrawal Point
— Influent Pipeline
- - - Effluent Pipeline
○ Water Sampling Site
H-4
Chlorination

Note: Site Location Numbers are Referred in Text

Scale: 1"=245 ft.

water throughout the reservoir. Quality of water delivered to consumers must meet USPHS, 1962, Drinking Water Standards. Influent water to Highland Reservoir has been treated at the Pittsburgh Water Treatment Plant receiving: prechlorination; flash mixing of water, alum, lime, permanganate, coagulant aid, and carbon; coagulation; sedimentation; filtration; pH control with soda ash; fluoridation; and postchlorination. Prechlorination is designed to maintain a concentration of 1-2 ppm residual chlorine through the plant. Postchlorination is used to maintain a concentration of 1-2 ppm residual chlorine in treatment plant effluent.

Treated water is stored in a clear well before being pumped directly to Highland Reservoir No. 1 receiving no additional treatment. Water is discharged through the influent chamber into the reservoir. Water in the reservoir is withdrawn from four effluent vaults located in different portions of the reservoir. Water in each effluent pipeline receives post-reservoir chlorination with the intention to insure that water received by consumers in the most distant portions of the distribution system has a residual chlorine concentration of 0.3-0.5 ppm. Additionally, first consumers are assured of adequate in-line contact time after postchlorination (50 min.-1970 flows).

Chlorination at the Pittsburgh Treatment Plant requires approximately 50 metric tons (55 short tons) of chlorine, per year (1975). This amount of chlorine is usually split evenly between chlorination of plant influent and effluent. The total annual cost at $0.17/kg ($154/ton) is $8,300/yr. Chlorination of effluent from Highland Reservoir requires about 17 metric tons (18 short tons) chlorine. During 1975, the total annual cost, at $0.36/kg ($325/ton), was $5,900/yr. Different unit costs of chlorine are attributed to the different forms and quantities used.

Water quality maintenance in the reservoir principally involves control of algal growth, shore plant growth, and prevention of contamination by illegal entry to the reservoir. Growth of algae is controlled by application of copper sulfate from a small boat to the water's surface, especially near the shore. During 1975, 39 applications were performed during summer and fall on the following basis: May - 2 applications, 1/week for 2 weeks; June - 4 applications, 1/week; July - 12 applications, 2/week; August - 12 applications, 3/week; September - 6 applications, 2/week; and October - 3 applications, 1/week for three weeks. The cost of copper sulfate alone was a total of $15,800/yr at $0.60/kg ($540/ton). Floating clumps of algae are removed by hand as necessary. During each application of copper sulfate, calcium hypochlorite (HTH) is also applied to control the growth of algae and prevent bacterial growths. Each of the 39 applications of HTH required about 500 kg (1,100 lb). The total cost of HTH during 1975 at $0.76/kg ($34.30/100 lb) was $14,800/yr.

Shore plant growth is controlled as required by intermittent cutting and removing of weeds.

Prevention of contaminant deposition by illegal entry to the reservoir is accomplished by periodic surveillance. Surveillance is provided by the Pittsburgh Police Department once every hour (24-hr day), the Pittsburgh

Park Police sporadically, and a civilian patrol consisting of volunteer walkers who will report security violations to police. Employees of the Water Department also provide security during their activities concerning operation of the reservoir.

Water Quality Problems

The public water supply of Pittsburgh has a long standing reputation of providing a very high quality water to its consumers. However, consumers occasionally complain of their water having unpleasant tastes and odors. These taste and odors have been associated with free floating algae in the reservoir. Algae may also cause turbidity problems of which consumers occasionally complain. As previously discussed, algal growths on the reservoir bottom will dislodge and enter the distribution system.

WATER QUALITY SAMPLING PROGRAM

Perspective of Sampling Program

Baseline information of Highland Reservoir No. 1 was collected in essentially the same manner as that of Druid Lake, Baltimore with only a few minor changes. These differences are presented in the next three sections concerning the routine sampling program; special sampling program; and characterization studies. Refer to Chapter IV of this report for a complete discussion of the items common to both reservoirs.

Routine Sampling Program

Water Quality Parameters

Water sampling and analysis of physical, chemical and biological parameters (Table V-1) in Highland Reservoir was performed by the Pittsburgh Water Department, according to the procedures in "Standard Methods" (Ref. V-1).

Sampling Sites and Time Period

Water samples are collected by the Pittsburgh Water Department at the following seven locations (shown in Figure V-1).

(H-1) Influent water chlorinated at treatment plant,

(H-2) Effluent water before post-reservoir chlorination,

(H-4) Effluent water before post-reservoir chlorination,

(H-5) Same effluent water as (H-4) but after post-reservoir chlorination,

(H-3) Same effluent water as (H-2) but after post-reservoir chlorination,

TABLE V-1

WATER QUALITY PARAMETERS AND ANALYTICAL TECHNIQUES USED IN STUDY OF HIGHLAND RESERVOIR NO. 1

Parameter	Analytical Technique (Ref. IV-5)
Chemical-Physical	
Temperature	Mercury Filled Thermometer
pH	Glass Electrode Method
Color, Apparent	Platinium-Cobalt Standard
Turbidity	Nephelometric Method
Total Solids	Filterable and Nonfilterable Solids
Dissolved Solids	Nonfilterable Solids
Alkalinity, Total	Standard Acid Titration
Hardness, Total	EDTA Titrimetric Method
Chlorine, Total Residual	Amperometric
Chlorine, Free Residual	Amperometric
Copper	Atomic Absorption, Spectrophotometric
Lead	Atomic Absorption, Spectrophotometric
Ammonia	Nesslerization Method
Nitrate	Brucine Method
Phosphate, Total	Stannous Chloride Method
Phosphate, Ortho, Soluble	Stannous Chloride Method
Phosphate, Ortho, Total	Stannous Chloride Method
Biological	
Coliforms, Total	Membrane Filter Technique
Coliforms, Fecal	Membrane Filter Technique
Plate Count, Total Standard	Standard Plate Count
Phytoplankton	Sedgwick-Rafter Procedure

(H-6) Effluent water after post-reservoir chlorination, and

(H-7) Effluent water after post-reservoir chlorination.

All parameters listed in Table V-1 are sampled from locations, H-1, H-2, H-4, H-6, and H-7. Only biological parameters are sampled at locations H-3 and H-5.

The sampling and analysis program began 1 February 1975, and ended on 31 January 1976. From 1 February 1975 to 31 May 1975, samples were collected from each sample site twice each week. Since the most significant water quality changes were expected to occur during the summer months, samples were collected from each location three times per week from 1 June 1975 to 30 September 1975. During the remainder of the study period, from 1 October to 31 January 1976, samples were collected at each location, twice each week.

As a check on existing conditions at the time of sampling, an "environmental check list" was compiled at the time of sampling for each sample data. The list included an estimation of: (1) air temperature; (2) presence and type of precipitation; (3) wind velocity; (4) presence of clouds; (5) numbers of birds on lake surface; (6) presence of waves; and (7) unusual activities on or around Highland Reservoir.

Special Sampling Program

The special sampling program for Highland Reservoir No. 1 is identical to that of Druid Lake, Baltimore, (discussed in Chapter IV) except for different sampling locations. The parameters, frequency of measurement, and EPA laboratory performing the analyses are listed in Table V-2. Water samples except those for microbial analysis were obtained at two static located at sites H-1 and H-2 (shown in Figure V-2). Microbial sampling was performed at stations H-1 and H-4.

Characterization Studies

Water Quality and Benthos Survey

Temperature and dissolved oxygen measurements were made on water sampled at 1.5 m. (5 ft.) intervals from surface to bottom at four locations (Figure V-2), H-A, H-B, H-C, and H-D. Bottom depth is about the same at all four locations.

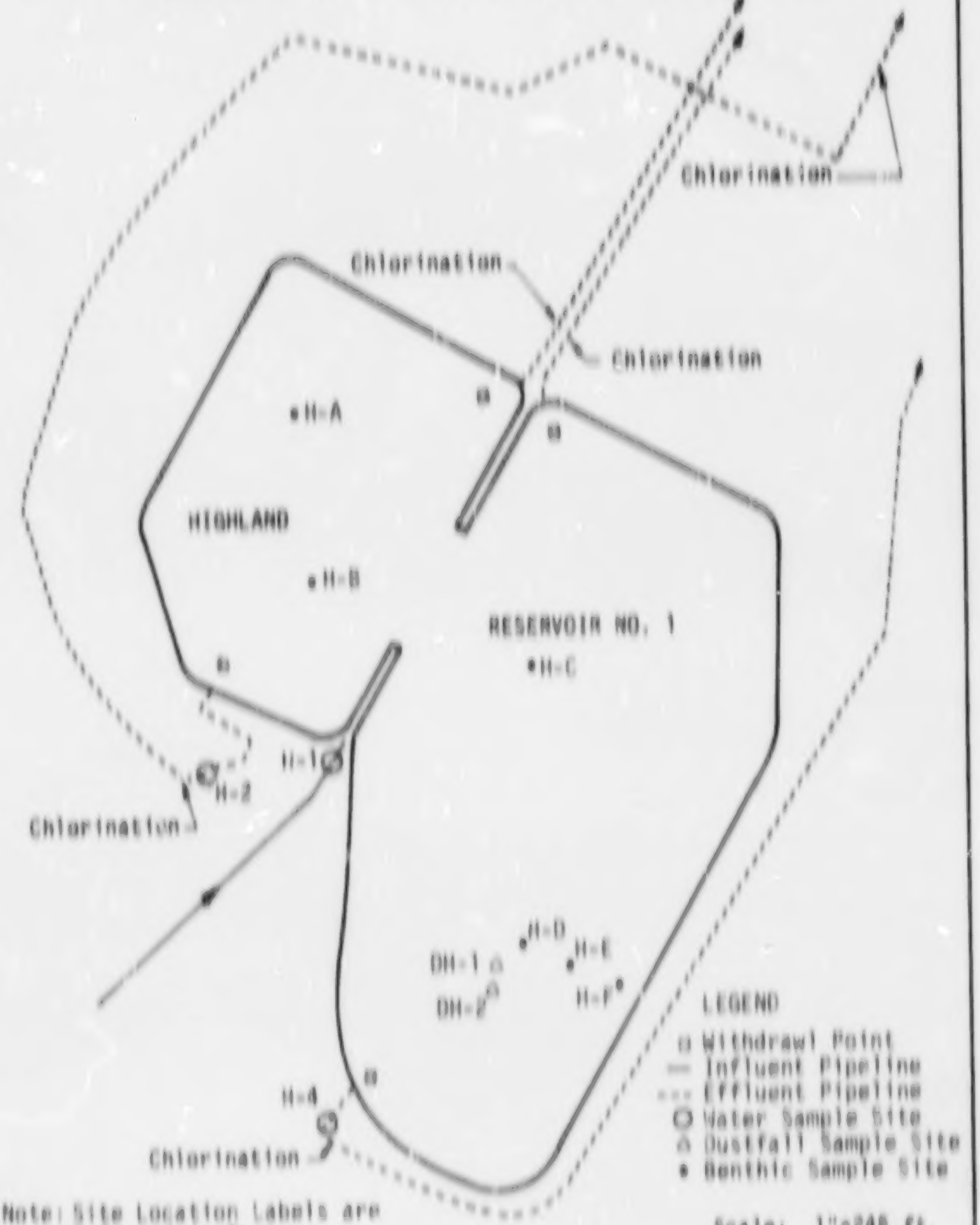
A qualitative survey of benthic organisms was made at the same three sites in conjunction with temperature and dissolved oxygen measurements. Two additional benthic survey locations (H-E and H-F) were included, thereby making a transect toward shore from location, H-D (Figure V-2). Microorganisms were identified by the Pittsburgh Water Department.

TABLE V-2

SPECIAL WATER QUALITY ANALYSES-HIGHLAND RESERVOIR NO. 1

Parameter	Frequency	EPA Laboratory
Total Organic Carbon	Weekly	Annapolis, Md.
Trace Metals	Monthly	Cincinnati, Ohio
Barium		
Chromium		
Copper		
Manganese		
Lead		
Iron		
Cadmium		
Zinc		
Radiochemical Isotopes	Quarter Yearly	Birmingham, Ala.
Gross beta		
Gross alpha		
Sr-90		
Ra-226		
Specific gamma		
Microbes	Quarter Yearly	Cincinnati, Ohio
Cytopathic viruses		
Coliform bacteria		

FIGURE V-2 LOCATION OF WATER SAMPLING SITES FOR HIGHLAND RESERVOIR NO. 1 SPECIAL WATER SAMPLING PROGRAM


Chlorination
Chlorination
Chlorination
H-A
HIGHLAND
H-B
RESERVOIR NO. 1
H-C
H-1
H-2
Chlorination
H-D
DH-1
H-E
DH-2
H-F
H-4
Chlorination
LEGEND
□ Withdrawl Point
— Influent Pipeline
--- Effluent Pipeline
◎ Water Sample Site
△ Dustfall Sample Site
● Benthic Sample Site

Note: Site Location Labels are
Referred in Text

Scale: 1"=240 ft.

Dustfall Sampling

The amount of airborne particulates settling upon Highland Reservoir was measured from March, 1975 to January, 1976. Two floating dustfall samplers were anchored in the reservoir, both in one area of the basin (see Figure V-2: stations DH-1 and DH-2). Sample collection was performed by the Pittsburgh Water Department on a monthly basis, and sample analysis was performed by the Pittsburgh Bureau of Air Pollution Control.

Potential Contamination by Birds

The surface of Highland Reservoir has no history of being used as a resting area by birds. No special sampling and analysis related to contamination by birds was performed.

Hydraulics of Highland Reservoir No. 1

A computation of average water detention time in Highland Reservoir No. 1 and flow through the reservoir was made for the year 1975. Existing information concerning reservoir volume was obtained from the Water Department. Effluent flows were also obtained from which the total effluent flow as well as effluent flows at each sampling station were derived.

Reservoir detention time was calculated using the annual average daily flow and the average reservoir volume.

EVALUATION OF WATER QUALITY DATA

Principles of Evaluation

Data were collected to characterize water quality of Highland Reservoir No. 1 and circumstances affecting water quality. The most important evaluation was to observe any relative water quality change from influent to effluent and effluent before and after postchlorination. Water quality data were also evaluated with respect to water quality standards; primarily those promulgated by the U.S. Public Health Service in 1962.

Data Presentation and Evaluation of Routine Sampling Program

Results of the routine sampling program (Table V-1) are presented in several levels of detail. A detailed listing of analytical results for all parameters at all sampling stations is located in the Appendix of this report (Table B-1). Information is shown by sample collection date, parameter, sampling site, and lower limit of analytical detection for the particular parameter. Data are presented for different sample dates in Table B-1 to account for reservoir detention time lag. This facilitates comparison of water quality between influent and effluent. The time lag between sample sites, before and after postchlorination is insignificant.

Between February, 1975 to May, 1975 the lag in Table B-1 is about 3.5 days; May, 1975 to November, 1975 = 2.5 days; and November, 1975 to January, 1976 = 3.5 days.

Data of the routine sampling program from the two prechlorination sampling stations (H-2 and H-4) were averaged together, to produce one value for one sampling date. Data from the four postchlorination sampling stations H-3, H-5, H-6, and H-7, were also averaged to produce one value for one sampling date. Influent samples were only collected at one station; therefore, no averaging procedure was necessary.

A weighted averaging procedure was required to manipulate the raw data because of unequal flows from the four effluent points in the reservoir. The flow at each sampling station was as follows:

Sample Stations		Water Flow	
		(cu.m./min.)	(mgd)
H-1	(influent)	76.5	29.1
H-2 and H-3	(effluent)	26.3	10.0
H-4 and H-5	(effluent)	33.1	12.6
H-6	(effluent)	9.2	3.5
H-7	(effluent	9.2	3.5

The sum of the four effluent flows does not equal the influent flow owing to inaccurate effluent flow metering. However, the effluent flows are used only relative to one another in calculating proportionate factors in the following equations.

The equation used to calculate the weighted average for prechlorination data is the following:

$$\text{average value} = (0.558)\ x_4 + (0.442)\ x_2$$

Where x_2 and x_4 are analytical results from sampling stations H-2 and H-4, respectively.

The two equations used to calculate the weighted average for postchlorination data is the following:

All parameters except biological parameters =

$$\text{average value} = (0.500)\ x_6 + (0.500)\ x_7$$

All parameters including biological parameters =

$$\text{average value} = (0.338)\ x_3 + (0.426)\ x_5 + (0.118)\ x_7 + (0.118)\ x_6$$

Where x_3, x_5, x_6, and x_7 are analytical values from sampling stations H-3, H-5, H-6, and H-7, respectively.

Routine sampling results in Table B-1 are summarized by presenting the monthly median and range for almost every parameter in tabular fashion. For each parameter, the range and median are given for each sample site. The parameters of ammonia and apparent color were not treated in this manner owning to their uniform values of measurement.

Of the parameters selected to present as monthly medians and ranges, four parameters were chosen as warranting additional analysis. This additional analysis is designed to evaluate the difference in parameter values between sample sites. To indicate the change in water quality visually, monthly median difference plots are presented. In order to evaluate the significance of the difference in water quality, a statistical analysis, Mann-Whitney 'U' Test was performed with data of the four parameters. Use of the Mann-Whitney 'U' Test is discussed in Chapter IV of this report.

Results of Data Evaluation

Routine Sampling Program

Temperature - Water temperature at the sampling locations of influent, effluent before postchlorination (here after known as prechlorinated effluent), and postchlorinated effluent display a seasonal trend following ambient temperature changes. Warmer water occurs during summer and cooler water during winter. This trend is shown by the monthly medians at all three sampling stations (see Table V-3).

Influent water temperatures are usually higher than or equal to prechlorination and postchlorination water temperature. Influent temperature measurements are higher during six months of the sampling period. Prechlorination and postchlorination temperatures are similar throughout the year.

Tap water with a temperature of 10°C (50°F) is generally satisfactory while temperatures above 15°C (59°F) are usually objectionable with possible consumer complaints above 19°C (66°F) (Ref. V-2). Water temperatures in Highland Reservoir exceed the limit of 15°C (59°F) during five months of summer at all three sampling locations. Most effluent temperatures are about 0.6-1.1°C (1-2°F) less than influent temperatures indicating that water cools within the reservoir, even during summer.

pH - On a yearly basis, pH measurements at the three sampling locations change little. Values of pH vary by about 0.4 units (see the data monthly medians in Table V-4). However, the pH measurement in February at the three sampling locations differs by about 1.0 unit from the pH values that occur during the remainder of the sampling period. This unusually high pH value is presumably caused by a change in treatment or transmission of water to Highland Reservoir during February.

Values of pH show little change (about 0.1 unit) from influent to the prechlorination location or from the prechlorination location to the

TABLE V-3

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - TEMPERATURE

Month 02/75–01/76	Temperature (°F)[1]					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	35–38	36	34–38	36	35–38	35
March	32–46	40	32–46	40	32–46	40
April	40–52	44	40–52	44	40–52	44
May	54–72	62	57–71	66	58–71	62
June	62–74	70	64–75	70	64–74	70
July	73–79	78	75–78	77	75–78	77
August	75–80	77	74–80	76	74–80	76
September	61–72	65	60–72	65	60–72	66
October	53–61	59	53–61	58	53–60	58
November	48–55	52	44–56	50	44–56	50
December	33–44	40	34–43	38	34–44	38
January	35–37	36	35–36	36	36–37	36

Note: (1) 32°F = lower limit of detection for temperature (one Centigrade deg. = 1.8 Fahrenheit deg.)

TABLE 6-4

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - pH

Month 02/75–01/76	pH (units)[1]					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	8.00–8.90	8.60	8.62–8.90	8.80	8.25–8.90	8.70
March	7.70–8.40	7.90	7.70–8.20	7.90	7.70–8.20	7.90
April	7.70–8.10	7.90	7.60–8.00	7.84	7.70–8.00	7.80
May	7.70–8.00	7.90	7.74–8.04	7.90	7.65–7.90	7.82
June	7.50–8.20	8.00	7.70–8.10	7.94	7.80–8.10	7.90
July	7.80–8.50	8.10	7.40–8.31	8.01	7.75–8.40	7.85
August	7.80–8.50	8.10	7.80–8.46	8.04	7.80–8.15	8.00
September	7.80–8.76	8.00	7.56–8.24	7.94	7.75–8.20	7.85
October	7.70–8.10	7.80	7.70–8.00	7.86	7.70–7.92	7.80
November	7.40–8.10	7.90	7.90–8.24	8.20	7.85–8.00	7.90
December	7.80–8.50	7.90	7.74–8.00	7.80	7.70–8.30	7.80
January	7.90–8.20	8.10	8.36–8.37	8.36	7.80–8.30	8.15

Note: (1) 0.01 unit = lower limit of detection for pH.

postchlorination location.

The USPHS Drinking Water Standards do not limit pH; however, values of pH in Highland Reservoir are within an acceptable range.

Color, apparent - Measurements of color do not change during the sampling period (see Appendix, Table B-1). All measurements of color are equal to or less than the lower limit of analytical detection; 1 unit. Every measurement of color is less than the USPHS standard (1962) of 15 units.

Turbidity - Influent concentrations of turbidity show a slight yearly trend of higher values during late spring and late summer-fall (see monthly median values in Table V-5). This trend of concentration change is carried through the reservoir, showing to a lesser extent at both effluent sampling locations.

Monthly median turbidity measurements (Table V-5) show about an equal number of concentration increases and decreases from influent to the prechlorination sampling location. However, values at the postchlorination sampling location show a general increase over prechlorination values.

All turbidity measurements are much less than the USPHS standard of 5 JTU, however, the National Interim Drinking Water Standards maximum turbidity level of 1.0 TU is violated occasionally by both influent and effluent waters.

Turbidity measurements during January are abnormally low at the prechlorination location. Measurements of other parameters, total solids, dissolved solids, total alkalinity, and total hardness at the prechlorination location during January are also abnormally low. While the parameters of turbidity, total solids dissolved solids, and possibly alkalinity are susceptible to contaminant sources outside the reservoir, total hardness is fairly independent of usual contaminant sources. Thus, measurements of the above parameters during January maybe subject to inaccurate laboratory analysis or reporting of results.

Total solids - Measurements of total solids (see monthly median values in Table V-6) show a distinct increase during summer at all three sampling locations. The trend of influent values throughout the sampling period is to a lesser extent, the same as the trend of both prechlorination and postchlorination values.

Total solids concentrations typically show little difference at the three sampling locations. Differences generally average about 7 mg/l.

The USPHS standards do not limit total solids. However the USPHS does set a limit on a component of total solids, dissolved solids, of 500 mg/l which is much higher than the usual value of about 190 mg/l found in Highland Reservoir No. 1.

Dissolved solids - Concentrations of dissolved solids, shown by monthly median values in Table V-7, are almost equal to those of total solids. Median values of dissolved and total solids usually differ by

TABLE V-5

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - TURBIDITY

Month 02/75-01/76	Turbidity (NTU)$^{(1)}$					
	Influent		Effluent-No Chlorination		Effluent-Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	0.05-0.10	0.05	0.03-0.09	0.05	0.05-0.20	0.09
March	0.12-1.40	0.50	0.11-0.78	0.52	0.11-0.77	0.58
April	0.18-0.96	0.35	0.12-0.73	0.26	0.15-1.20	0.25
May	0.75-1.50	0.92	0.50-0.92	0.60	0.67-1.40	0.67
June	0.12-4.70	0.73	0.40-5.00	0.58	0.27-4.80	0.94
July	0.08-0.85	0.26	0.25-0.88	0.45	0.40-1.20	0.65
August	0.06-1.20	0.15	0.26-0.96	0.30	0.20-1.10	0.38
September	0.34-1.30	1.00	0.50-4.50	0.96	0.53-1.80	0.97
October	0.48-1.30	0.82	0.23-1.20	0.63	0.32-1.10	0.60
November	0.70-2.60	0.99	0.53-0.96	0.72	0.65-1.01	0.90
December	0.15-0.60	0.50	0.24-0.88	0.53	0.34-0.77	0.56
January	0.35-0.61	0.48	0.20-0.54	0.30	0.28-0.72	0.60

Note: 0.05 NTU = lower limit of detection for turbidity.

TABLE V-6

MONTHLY MEDIANS AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - TOTAL SOLIDS

Month 02/75–01/76	Total Solids (mg/l)[1]					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	156–220	175	94–202	186	159–201	182
March	145–186	170	156–187	179	153–185	179
April	152–189	160	145–177	158	148–180	157
May	171–217	195	178–234	204	180–235	207
June	152–248	168	152–236	170	158–225	184
July	187–340	289	196–331	273	196–335	274
August	294–341	322	306–336	321	302–338	325
September	195–257	221	202–286	229	203–285	232
October	160–217	185	180–216	186	177–221	190
November	168–206	179	171–198	174	171–208	175
December	122–195	162	136–196	157	128–197	156
January	135–202	172	76–190	97	136–196	170

Note: (1) 1 mg/l = lower limit of detection for total solids.

TABLE V-7

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA HIGHLAND RESERVOIR NO. 1 - DISSOLVED SOLIDS

Month 02/75–01/76	Dissolved Solids (mg/l)[1]					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	136–204	171	86–183	178	134–187	178
March	144–194	170	155–185	177	152–183	176
April	147–184	159	140–173	148	145–176	153
May	172–215	184	175–232	202	178–233	203
June	147–247	164	151–234	167	156–234	168
July	185–340	288	193–330	272	193–333	275
August	280–326	322	305–335	321	303–337	318
September	193–300	221	201–281	225	202–283	224
October	159–216	184	179–207	184	176–219	182
November	167–205	178	170–197	172	169–198	173
December	121–195	161	135–195	155	126–195	154
January	134–200	171	75–197	96	125–197	169

Note: (1) 1 mg/l = lower limit of detection for dissolved solids.

about 2-4 mg/l. This relationship indicates that most components of total solids are contributed by dissolved solids.

All concentrations of dissolved solids meet the USPHS recommended drinking water standard of 500 mg/l.

Total alkalinity - Monthly median concentrations of alkalinity, shown in Table V-8, indicate that values at both effluent sampling locations follow the influent yearly trend of slightly higher concentrations during late summer and during fall. However, with the exception of concentrations during January at the prechlorination sampling location which show unusually low values, all other measurements differ by a maximum of 12 mg/l during the year.

Spatial differences in alkalinity values show little difference between sampling locations (except for the values during January at the prechlorination location). Concentrations change by about 1-2 mg/l between stations.

The USPHS has set no limit on alkalinity. Considering the low values of dissolved solids and small deviation of pH from neutrality (typical pH of 8.0 units) in Highland Reservoir, all concentrations of alkalinity are within an acceptable range.

Hardness - Concentrations of hardness at both effluent stations follow the same yearly trend as indicated by influent monthly median concentrations shown in Table V-9. This trend indicates high values during summer and decreasing values during fall.

Hardness measurements change only slightly between sampling locations. The data monthly median values displayed in Table V-9 show differences of only 1-2 mg/l between prechlorination and postchlorination locations. Concentrations at the prechlorination location during January are lower than the majority of hardness values.

No limit on hardness has been set by the USPHS. High quality drinking water usually has a concentration of hardness less than 100 mg/l. However, water may have acceptable concentrations of hardness up to 270 mg/l (Ref. V-2). All of the concentrations in Highland Reservoir No. 1 during July, August, and September exceed 100 mg/l hardness. Values during the remainder of the year fluctuate near 100 mg/l. However, all hardness concentrations are much less than 270 mg/l. From the standpoint of hardness, the water of Highland Reservoir is of good quality.

Total chlorine - Interpretation of total residual chlorine sampling results (as well as free residual chlorine results) must be performed with the realization that post-reservoir chlorination was only performed from 1 June to 1 October 1975.

Influent concentrations of total chlorine tend to show higher values during summer and fall in Highland Reservoir No. 1 (see median values

TABLE V-8

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - TOTAL ALKALINITY

Month 02/75-02/76	Total Alkalinity (mg/l)[1]					
	Influent		Effluent-No Chlorination		Effluent-Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	30-37	37	18-38	35	30-38	35
March	23-29	26	27-29	26	23-29	26
April	24-30	26	24-28	26	24-28	26
May	22-30	26	23-28	27	23-28	27
June	23-38	31	26-35	30	26-33	29
July	25-42	29	26-35	28	25-35	27
August	30-40	38	31-42	37	31-42	37
September	33-47	35	33-37	34	32-39	34
October	26-35	30	28-33	30	28-33	30
November	29-38	32	32-34	33	30-34	33
December	29-36	34	29-34	31	29-33	31
January	28-33	29	16-31	17	27-32	29

Note: (1) 1 mg/l = lower limit of detection for total alkalinity.

TABLE V-4

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - HARDNESS

Month 02/75-01/76	Hardness (as $CaCO_3$)(mg/l)(1)					
	Influent		Effluent-No Chlorination		Effluent-Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	90-108	98	50-101	97	88-100	98
March	80- 92	88	85- 91	88	81- 91	87
April	84-110	88	84-103	86	84-100	88
May	86-112	98	91-111	102	89-117	100
June	92-118	98	90-112	99	93-112	97
July	100-166	140	113-159	139	112-161	139
August	150-164	160	151-168	162	152-168	162
September	106-136	118	110-143	120	109-143	120
October	92-126	108	93-112	108	94-114	109
November	88-104	102	97-105	104	97-107	107
December	88-114	96	84-112	97	84-110	97
January	90-102	98	48-112	57	90-112	97

Note: (1) 1 mg/l = lower limit of detection for hardness (as $CaCO_3$).

in Table V-10). Both effluent prechlorination and postchlorination sampling locations show this yearly trend but to a more limited extent.

All measurements of total chlorine at the postchlorination location (indicated by monthly median values) are less than influent values by 0.15 to 0.85 mg/l during the year. Total chlorine is a expression of both free and combined chlorine residuals. The loss of total chlorine from reservoir influent to effluent may be atrributed to many factors. Chlorine in water is a very active chemical agent; it reacts with the many substances dissolved or suspended in water. Reducing compounds (e.g., manganese, iron, nitrites, etc) and organic matter that are continually being transported into the reservoir via groundwater, precipitation, wind photosynthesis, etc. exert a chlorine demand. The large reservoir volume affords the opportunity and time for these substances to react with chlorine. Consequently, various amounts of available chlorine are being removed, depending on the amount of chlorine demanding substances that are present. Additionally, sunlight dissipates chlorine in large, open reservoirs.

During the course of the sampling period there was consistently little difference in total chlorine residual concentrations in the effluent before chlorination and after chlorination. Moreover, postchlorinated effluent was not consistently maintained at the total residual chlorine concentrations intended by the Water Department (0.3 - 0.5 ppm). Evidently, the postchlorination of reservoir effluent, as practiced that year, was either insufficient to maintain these residuals, or non-existent.

The USPHS has set no limits upon total chlorine concentration. However, the threshold of taste in redistilled water is about 5 mg/l (Ref. V-2). All measurements of total chlorine in Highland Reservoir No. 1 are less than this limit. Because of chlorine is added as a disinfectant, the loss of chlorine is of primary concern.

Free chlorine - On a yearly basis, concentrations of free residual chlorine (indicated by the monthly medians of Table V-11) follow similar trends at all three sampling locations. Higher values occur during late summer and late fall-winter. This trend is generally the same as the yearly trend of total chlorine concentrations. However, concentrations of residual chlorine are not consistently proportional to concentrations of total chlorine indicating the presence of varying amounts of combined chlorine residuals during the course of the year. For example, differences in concentrations of total and residual chlorine at the prechlorination sampling location range from 0.02 mg/l in April to 0.69 mg/l in November.

As in the case of total chlorine, all concentrations of residual chlorine at the effluent prechlorination sampling location are less than influent concentrations. The difference in effluent total chlorine residuals and free chlorine residuals may be attributed to the formation of chloramines in the reservoir due to traces of ammonia in the water. These chloramines have less disinfecting capability than chlorine in the free form, however they tend to last longer and therefore afford bactericidal protection to drinking water in the outmost portions of the distribution system. Free chlorine concentrations at the effluent postchlorination location are the same or slightly less than effluent prechlorination values (typically 0.02 mg/l less). This slight difference again shows that the postchlorination operation has little effect

TABLE V-10

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - TOTAL CHLORINE

Month 02/75-01/76	Total Chlorine (mg/l)(1)					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	0.15-0.75	0.29	0.06-0.27	0.13	0.10-0.25	0.10
March	0.26-1.37	0.55	0.11-0.52	0.29	0.10-0.46	0.26
April	0.08-1.00	0.48	0.01-0.22	0.05	0.01-0.23	0.05
May	0.45-1.26	0.80	0.06-0.74	0.46	0.04-0.87	0.38
June	0.15-1.30	0.58	0.01-0.39	0.07	0.01-0.50	0.08
July	0.01-4.00	0.82	0.07-0.87	0.54	0.04-0.93	0.51
August	0.23-1.90	0.84	0.10-0.86	0.31	0.05-0.88	0.30
September	0.12-1.84	0.66	0.01-0.75	0.50	0.07-1.15	0.61
October	0.42-1.97	0.73	0.05-0.92	0.13	0.05-0.71	0.09
November	0.21-1.49	1.12	0.50-1.30	0.79	0.14-1.90	0.58
December	0.42-2.50	1.20	0.17-0.64	0.35	0.15-0.71	0.27
January	0.39-1.24	0.59	0.06-0.37	0.17	0.09-0.38	0.18

Note: (1) 0.01 mg/l = lower limit of detection for total chlorine.

TABLE [illegible]

MONTHLY MEDIAN AND RANGE OF EXISTING WATER SAMPLING DATA AND PROBABILITY OF ALTERED WATER QUALITY [illegible] NO. 1 - FREE CHLORINE

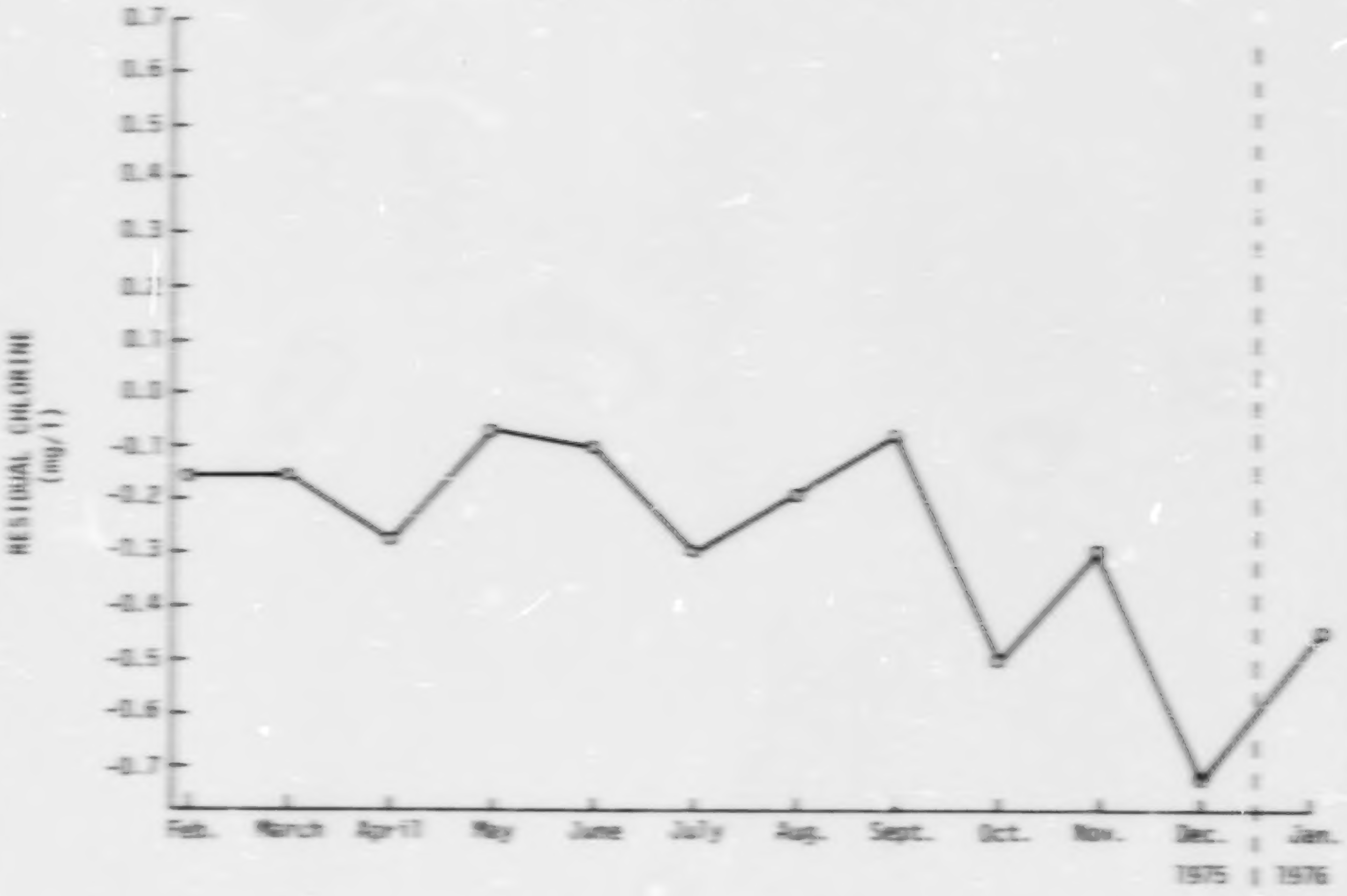
Month	Free Chlorine Residual, mg/l[1]									
	Sample Sites						Mann-Whitney "U" Test[2] Influent-Effluent, No Cl_2			
	Influent		Effluent-No Chlorination		Effluent-Post Chlorination					
[illegible]	Range	Median	Range	Median	Range	Median	U_c	U_α	α	Probability of Unequal Conc. (%)
February	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
September	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
November	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
December	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
January	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Notes: (1) [illegible] mg/l = Lower limit of detection for residual chlorine.

(2) [illegible]

* [illegible]

FIGURE V-3 MONTHLY MEDIAN DIFFERENCES (PRECHLORINATION MINUS INFLUENT)
FREE CHLORINE RESIDUAL FOR DRUID LAKE



upon chlorine concentration in affluent water.

Because free residual chlorine is important to disinfection of the water supply and because of the additional cost incurred by applying chlorine, the Mann Whitney 'U' Test was used to statistically evaluate the difference of concentrations between influent and prechlorination effluent. While differences in water quality data between influent and effluent have previously been observed, no attempt was made to identify the significance of the difference. Results from the statistical analysis of residual chlorine (Table V-11) indicate that for all months of the sampling period the probability of different concentrations between influent and prechlorinated effluent is greater than the 90 percent confidence level with most months showing a probability greater than 99 percent.

The USPHS has set no limits upon concentrations of residual chlorine.

Copper - Concentrations of copper, indicated by the monthly median values in Table V-12, show no yearly or spatial change in any of the three sampling locations. Most values are less than or equal to the lower limit of detection (0.010 mg/l) used in analysis. However, during August measurements of copper greater than 0.010 mg/l occur sporadically (Appendix, Table B-1) at the influent, prechlorination, and postchlorination sampling locations. These periods of increased copper in the effluent are most likely a result of the manual applications of copper sulfate (algacide) that are not uniformly distributed.

The USPHS has recommended a limit on copper of 1.0 mg/l for domestic water supplies. This limit is primarily based on threshold concentrations of taste which are in the range of 1.0-2.0 mg/l. All reported copper concentrations in Highland Reservoir No. 1 are much less than 1.0 mg/l.

Lead - The monthly median concentrations of lead at all sampling stations (Table V-13) show a yearly trend of highest concentrations occurring in late spring-early summer and lowest concentrations during winter. The prechlorination and postchlorination sampling locations show an additional peak during November. A moderate change of concentration exists at each sampling location where the maximum difference at the influent sampling station is 0.017 mg/l; prechlorination location - 0.022 mg/l; and postchlorination location - 0.028 mg/l.

Measurements of lead generally increase from influent to the postchlorination sampling location. During seven months of the sampling period (see monthly medians of Table V-13), lead values at the prechlorination location exceed influent concentrations by 0.001 to 0.013 mg/l (Figure V-4). Prechlorination lead values exceed postchlorination lead values during seven months of the year (not necessarily the same seven months as above) by 0.002 to 0.006 mg/l.

The increase in lead concentration through Highland Reservoir No. 1 might be due to contamination by settled lead particulates from the air Unfortunately no lead particulate monitoring is performed in Pittsburgh which could confirm this possibility.

TABLE V-12

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - COPPER

Month 02/75–01/76	Copper (mg/l)[1]					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	0.010	0.010	0.010	0.010	0.010	0.010
March	0.010	0.010	0.010	0.010	0.010	0.010
April	0.010	0.010	0.010	0.010	0.010	0.010
May	0.010	0.010	0.010	0.010	0.010	0.010
June	0.010	0.010	0.010	0.010	0.010	0.010
July	0.025	0.010	0.010	0.010	0.010	0.010
August	0.010–0.200	0.010	0.010–0.150	0.010	0.010–0.080	0.010
September	0.010	0.010	0.010	0.010	0.010	0.010
October	0.010	0.010	0.010	0.010	0.010	0.010
November	0.010	0.010	0.010	0.010	0.010	0.010
December	0.010	0.010	0.010	0.010	0.010	0.010
January	0.010	0.010	0.010–0.086	0.010	0.010	0.010

Note: (1) 0.001 mg/l = lower limit of detection for copper, however the lower analytical detection limit generally utilized is 0.010.

[illegible]

[illegible]

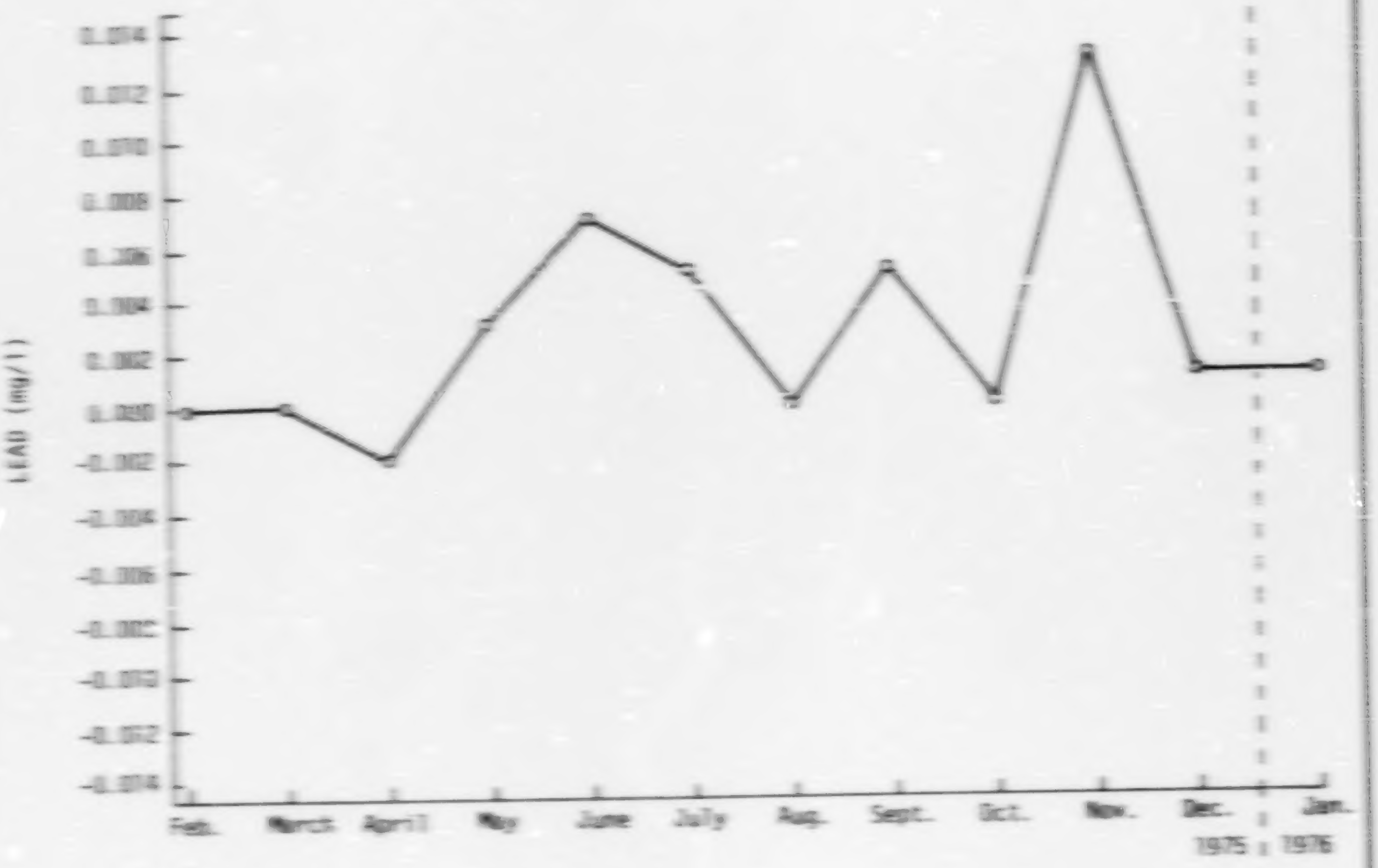
Month	Lead (mg/l)									
	Sample Sites						Mann-Whitney "U" Test			
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination		Influent-Effluent, No Cl_2			
	Range	Median	Range	Median	Range	Median	U_a	U_b	α	Probability of Unequal Conc. (%)
February	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
September	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
November	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
December	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
January	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Note: (1) [illegible]

(2) [illegible]

* [illegible]

FIGURE 6-4 MONTHLY MEDIAN DIFFERENCES (PRECHLORINATION MINUS INFLUENT)
LEAD FOR HIGHLAND RESERVOIR



Evaluation of differences between influent and prechlorination lead concentrations was performed by testing for significance using the Mann-Whitney 'U' Test. Results indicate that the probability of dissimilar concentrations is 95-99 percent during the months of July, September, and November. The probability is less than 90 percent during the remainder of the year. Therefore a significant difference in lead concentration only occurred intermittently during the sampling period.

The USPHS has set a limit of 0.05 mg/l lead concentration for drinking water. All lead values in Highland Reservoir are less than 0.05 mg/l.

Ammonia - Measurements of ammonia at the prechlorination and postchlorination sampling locations follow the same yearly trend as that of the influent sampling station where ammonia concentrations peak in July and August (see monthly median values in Table V-14). However, most ammonia measurements are equal to the lower limit of detection, 0.02 mg/l (Appendix, Table B-1).

The difference in concentration of ammonia between sampling locations is negligible.

While the USPHS has set no limits on ammonia concentration, a generally accepted limit indicating sanitary condition is approximately 0.04-0.08 mg/l ammonia as N (Ref. V-2). Concentrations at all three sampling locations sporadically exceed this limit during July and August.

Nitrate - No yearly trend of nitrate concentrations at any of the three sampling locations is apparent from the monthly median values of Table V-15. Measurements of nitrate differ during the sampling period at the influent sampling location by a maximum of 0.40 mg/l; prechlorination location - 0.50 mg/l.

Spatially, nitrate concentrations differ little between sampling locations. Prechlorination concentrations exceed influent values by 0.04 to 0.11 mg/l, while the difference in concentration between prechlorination and postchlorination locations is negligible.

The USPHS has recommended a limit of 10 mg/l nitrate as N. All concentrations of nitrate in Highland Reservoir are much less than 10 mg/l.

Total phosphate - The monthly median concentrations of total phosphate (as PO_4), shown in Table V-16, are all equal to or less than the lower limit of analytical detection (0.01 mg/l) at the three sampling locations. No changes in concentration occur either temporally or spatially. However, intermittent increases in concentration exist at the three sampling locations during the sampling period (Appendix, Table B-1). The period of highest total phosphate concentrations occurs during July and August.

TABLE V-14

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - AMMONIA

Month 02/75–01/76	Ammonia (as N) (mg/l)[1]					
	Influent		Effluent– No Chlorination		Effluent– Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	0.02	0.02	0.01–0.02	0.02	0.02	0.02
March	0.02–0.06	0.02	0.02–0.04	0.02	0.02–0.04	0.02
April	0.02	0.02	0.02	0.02	0.02	0.02
May	0.02–0.04	0.02	0.02–0.05	0.02	0.02–0.04	0.02
June	0.02–0.05	0.02	0.02–0.04	0.02	0.02–0.04	0.02
July	0.02–0.22	0.05	0.02–0.18	0.07	0.02–0.21	0.07
August	0.02–0.13	0.09	0.02–0.14	0.08	0.02–0.14	0.08
September	0.02	0.02	0.02	0.02	0.02	0.02
October	0.02	0.02	0.02	0.02	0.02	0.02
November	0.02	0.02	0.02	0.02	0.02	0.02
December	0.02	0.02	0.02	0.02	0.02	0.02
January	0.02	0.02	0.01–0.02	0.02	0.02	0.02

Note: (1) 0.02 mg/l = lower limit of detection for ammonia (as N).

TABLE V-15

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - NITRATE

Month 02/75–01/76	Nitrate (as N) (mg/l)[1]					
	Influent		Effluent–No Chlorination		Effluent–Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	0.60–0.90	0.60	0.34–0.86	0.71	[illegible]	0.70
March	0.40–0.70	0.60	0.60–0.70	0.60	[illegible]	0.75
April	0.60–1.00	0.80	0.80–1.00	0.90	0.70–1.20	0.90
May	0.20–0.90	0.40	0.30–0.80	0.40	0.25–0.55	0.40
June	0.40–1.00	0.60	0.40–1.00	0.60	0.45–0.86	0.60
July	0.30–0.80	0.50	0.30–0.60	0.50	0.35–0.70	0.50
August	0.20–1.20	0.90	0.36–1.10	0.90	0.30–1.10	0.90
September	0.50–1.10	0.60	0.56–0.80	0.70	0.65–0.80	0.65
October	0.40–0.90	0.70	0.50–0.90	0.80	0.55–0.90	0.75
November	0.50–0.90	0.50	0.50–0.70	0.56	0.45–0.75	0.55
December	0.50–0.80	0.70	0.36–0.90	0.70	0.60–0.90	0.70
January	0.60–1.00	0.80	0.34–0.94	0.84	0.70–1.00	0.85

Note: (1) 0.01 mg/l = lower limit of detection for nitrate (as N).

TABLE V-16

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - TOTAL PHOSPHATE

Month 02/75–01/76	Total Phosphate (as PO_4)(mg/l)[1]					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	0.01–0.15	0.01	0.01–0.12	0.01	0.01–0.10	0.01
March	0.01	0.01	0.01–0.10	0.01	0.01–0.06	0.01
April	0.01–0.15	0.01	0.01–0.05	0.01	0.01	0.01
May	0.01	0.01	0.01	0.01	0.01	0.02
June	0.01	0.01	0.01	0.01	0.01	0.01
July	0.01–0.10	0.01	0.01–0.13	0.01	0.01–0.20	0.01
August	0.01–0.20	0.01	0.01–0.12	0.01	0.01–0.15	0.01
September	0.01	0.01	0.01	0.01	0.01	0.01
October	0.01–0.25	0.01	0.01	0.01	0.01	0.01
November	0.01–0.10	0.01	0.01	0.01	0.01	0.01
December	0.01–0.10	0.01	0.01–0.10	0.01	0.01	0.01
January	0.01	0.01	0.01	0.01	0.01	0.01

Note: (1) 0.01 mg/l = lower limit of detection for total phosphate (as PO_4).

No limits upon total phosphate have been set by the USPHS. The presence of phosphate in Highland Reservoir is of primary importance as a bionutrient. Threshold phosphate requirements for biological growth depend upon climate and the chemical and physical character of the water. Dissolved (soluble) inorganic phosphate (usually orthophosphate) is the most readily assimilated form of phosphate. Insoluble orthophosphate is also a used form. Comparison of total phosphate concentrations with concentrations of soluble orthophosphate and total orthophosphate (soluble plus insoluble phosphate) indicate that during most of the sampling period, concentrations of all forms of phosphate are less than or equal to the lower limit of analytical detection (Appendix, Table B-1). Increased concentrations of total phosphate are not accompanied by increased concentrations of total and/or soluble orthophosphate indicating that the increase in total phosphate is probably due to the presence of higher levels of organic phosphate.

Soluble orthophosphate - All but a few measurements of soluble orthophosphate are less than or equal to the lower limit of analytical detection, 0.01 mg/l (Appendix, Table B-1) at the three sampling locations.

The USPHS has set no limits on soluble orthophosphate concentration. This inorganic form of phosphate is a more specific plant nutrient than total phosphate. A suggested maximum concentration of inorganic phosphorus is 0.01 mg/l which can be permitted without encouraging plant growth (Ref. V-2). If this limit of phosphorus is expressed in terms of phosphate then the maximum concentration is about 0.03 mg/l (as PO_4). The number of measurements of soluble orthophosphate in Highland Reservoir No. 1 that exceed 0.03 mg/l are negligible.

Total orthophosphate - As in the case of soluble orthophosphate, all but a few measurements of total orthophosphate are less than or equal to the lower limit of analytical detection, 0.01 mg/l (Appendix, Table B-1) at the three sampling locations.

No concentration limits have been set for total orthophosphate by the USPHS. Total orthophosphate is a more comprehensive measure of inorganic phosphate than soluble orthophosphate. The criterion on inorganic phosphate (0.03 mg/l) developed in the section evaluating results of soluble orthophosphate analyses is valid for limiting total orthophosphate. The number of measurements of total orthophosphate in Highland Reservoir that exceed 0.03 mg/l are negligible.

Total coliforms - Measurements of total coliform bacteria (Table V-17) indicate that at all sampling locations during the entire sampling period, total coliforms are practically nonexistent.

The USPHS limits the average monthly coliform content of drinking water to a limit of one per 100 ml. All total coliform measurements are less than or equal to this limit except for a negligible three measurements at the postchlorination location.

TABLE V-17

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA
HIGHLAND RESERVOIR NO. 1 - TOTAL COLIFORMS

Month 02/75–01/76	Total Coliforms (colonies/100 ml)[1]					
	Influent		Effluent- No Chlorination		Effluent- Post Chlorination	
	Range	Median	Range	Median	Range	Median
February	<1	<1	<1	<1	<1	<1
March	<1	<1	<1	<1	<1	<1
April	<1	<1	<1	<1	<1	<1
May	<1	<1	<1	<1	<1	<1
June	<1	<1	<1	<1	<1	<1
July	<1	<1	<1	<1	<1	<1
August	<1	<1	<1	<1	1-2	<1
September	<1	<1	<1	<1	1-2	<1
October	<1	<1	<1	<1	<1	<1
November	<1	<1	<1	<1	<1	<1
December	<1	<1	<1	<1	<1	<1
January	<1	<1	<1	<1	<1	<1

Note: (1) 1 Colony/100 ml - lower limit of detection for total coliforms.

Total standard plate count - Measurements of bacteria (indicated by total standard plate count) at the three sampling locations show a yearly trend of increasing concentrations during summer and early fall (see monthly median values in Table V-18). Higher bacterial concentrations tend to occur sooner during the sampling period at sampling locations more distant from the influent location. Concentrations start increasing at the influent location in August, the effluent prechlorination location in July; and the postchlorination location in July (Appendix, Table B-1). This earlier growth initiation is probably caused by more favorable growth conditions in the reservoir.

Measurements of bacteria during the summer period of higher concentrations show slight increases from the influent location through the reservoir to the postchlorination location (see Figures V-5 and V-6). This spatial trend indicates that the chlorination operations were ineffective in eliminating bacterial growth. During the remainder of the sampling period, bacteria concentrations generally decrease from the influent location to the effluent prechlorination location and remain about the same from the prechlorination location to the postchlorination location.

The Mann-Whitney 'U' Test was used to determine the significance of the difference in bacterial concentrations between influent and prechlorinated effluent, and effluent before and after postchlorination. Results from the statistical analysis of influent/prechlorinated effluent data (Table V-18) show that the probability of dissimilar concentrations is greater than 95 percent during most of the sampling period other than during summer. The significant differences (above a 90 percent confidence level) between concentrations at the two locations are decreases from influent to prechlorinated effluent in all cases. Most increases are insignificant. Results from the statistical analysis of prechlorination and postchlorination effluent data (Table V-18) show that the probability of dissimilar concentrations is generally less than 90 percent except during July and September. Thus, differences between bacterial concentrations at the effluent prechlorination and postchlorination locations are small.

Influent residual chlorine concentrations to Highland Reservoir No. 1 appear sufficient to maintain low bacteria concentrations during late fall, winter, and spring. Residual chlorine concentrations are not, however, sufficient to prevent the growth of bacteria during the summer and early fall. Moreover, chlorination of reservoir effluent does not appreciably kill bacteria that have grown in the reservoir.

The USPHS has not set limits upon bacteria density as indicated by the total standard plate count procedure.

Phytoplankton - The monthly median concentrations of phytoplankton shown in Table V-19, indicate that during at least half of every month, no phytoplankton were detected in Highland Reservoir No. 1 at the three sampling locations. Phytoplankton concentrations shown in Table B-1 (Appendix)

TABLE [illegible]

MONTHLY MEDIAN AND RANGE OF [illegible] WATER SAMPLING DATA AND PROBABILITY OF ALTERED WATER QUALITY [illegible] RESERVOIR NO. [illegible] — TOTAL STANDARD PLATE COUNT

Month	Total Standard Plate Count (colonies/ml)[1]													
	Sample Sites						Mann-Whitney "U" Test[2]							
							Influent-Effluent, No Cl_2				Effluent, No Cl_2-Effluent, Post Cl_2			
	Influent		Effluent-No Chlorination		Effluent-Post Chlorination									
	Range	Median	Range	Median	Range	Median	U_a	U_b	α	Probability of Unequal Conc. (%)	U_a	U_b	α	Probability of Unequal Conc. (%)
February	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
September	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] *
October	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
November	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
December	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
January	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Note: (1) 1 colony/ml = lower limit of detection for total standard plate count.

(2) One directional test for equal concentrations of bacteria (total standard plate count) at sampling sites: influent and effluent-no chlorination, and effluent-no chlorination and effluent-post chlorination. The significance level is set at "α". The statistic U_a is computed and compared to U_b which is selected at "α" or the larger "α" if stated as a range. U_a must be less than U_b to state with some confidence probability greater than 90% that the concentrations at the two sample sites differ. Where a single number is listed beneath columns U_a and U_b, a probability was computed directly with "α" to determine the confidence probability.

* Denotes value greater than 90%.

FIGURE 9-5 MONTHLY MEDIAN DIFFERENCES (PRECHLORINATION MINUS INFLUENT)
TOTAL STANDARD PLATE COUNT FOR HIGHLAND RESERVOIR

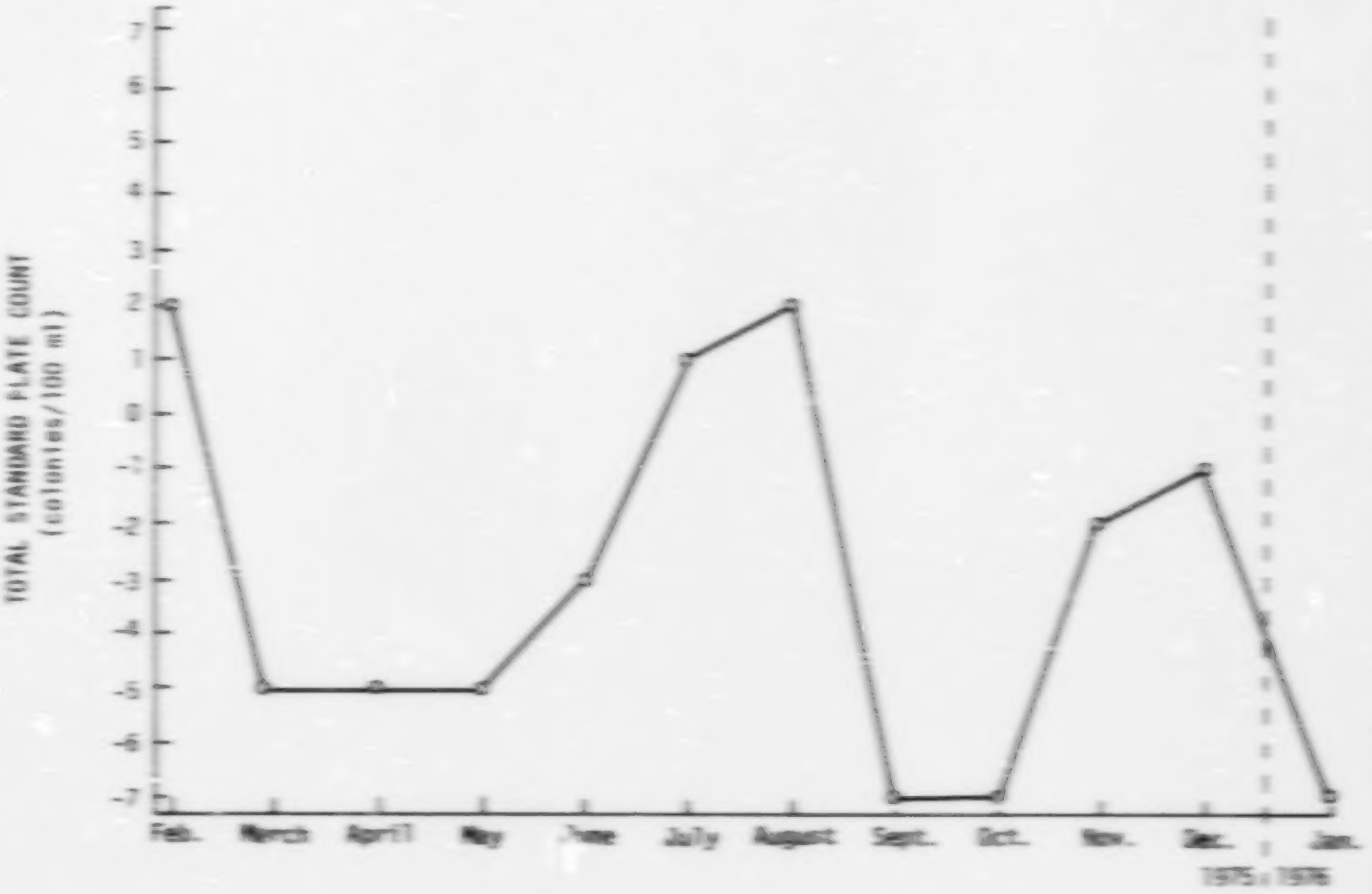


FIGURE V-6 MONTHLY MEDIAN DIFFERENCES (POSTCHLORINATION MINUS PRECHLORINATION) TOTAL STANDARD PLATE COUNT FOR HIGHLAND RESERVOIR

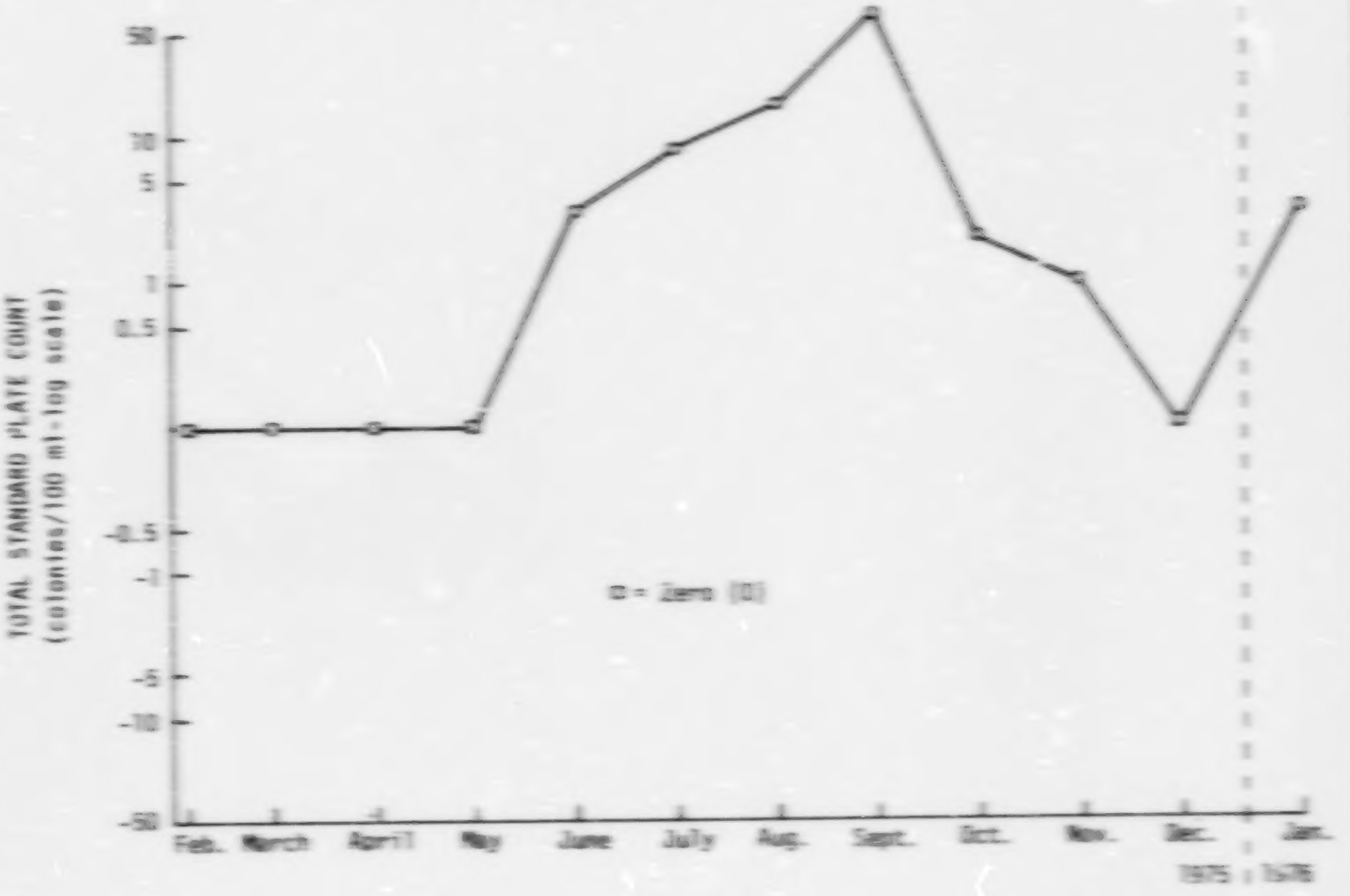


TABLE [illegible]

MONTHLY MEDIAN AND RANGE OF ROUTINE WATER SAMPLING DATA AND PROBABILITY OF ALTERED WATER QUALITY HIGHLAND RESERVOIR NO. 1 – PHYTOPLANKTON

Month	Phytoplankton (organisms/ml)[1]													
	Sample Sites						Mann-Whitney "U" Test[2]							
							Influent-Effluent, No Cl_2				Effluent, No Cl_2-Effluent, Post Cl_2			
1975-1976	Influent		Effluent-No Chlorination		Effluent-Post Chlorination					Probability of Unequal Conc. (%)				Probability of Unequal Conc. (%)
	Range	Median	Range	Median	Range	Median	U_o	U_α	α		U_o	U_α	α	
February	0	0	1	0	0	0	0.320		<0.1	<90	0.320		<0.1	<90
March	0	0	0	0	0	0	54.5	21	<0.1	<90	40.5	21	<0.1	<90
April	0	0	0	0	0	0	0.320		<0.1	<90	0.320		<0.1	<90
May	0	0	0	0	0	0	60.5	21	<0.1	<90	40.5	21	<0.1	<90
June	0	0	0-4	0	0-4	0	66.0	42	<0.1	<90	44.5	42	<0.1	<90
July	1	0	0-40	0	0-56	0	52.0	42	<0.1	<90	44.5	42	<0.1	<90
August	0-41	0	0-56	0	0-100	0	70.5	55	<0.1	<90	78.5	47	<0.1	<90
September	0	0	0	0	0	0	72.0	42	<0.1	<90	72.0	42	<0.1	<90
October	0	0	0	0	0	0	54.0	27	<0.1	<90	54.0	27	<0.1	<90
November	0	0	2	0	0	0	0.340		<0.1	<90	0.340		<0.1	<90
December	0	0	0	0	0	0	0.320		<0.1	<90	0.320		<0.1	<90
January	0	0	1	0	0	0	0.330		<0.1	<90	0.330		<0.1	<90

Note: [1] 0 organisms/ml = lower limit of detection for phytoplankton.

[2] Non directional test for equal concentrations of phytoplankton at sampling sites: influent and effluent-no chlorination, and effluent-no chlorination and effluent-post chlorination. The significance level is set at "α". The statistic U_o is computed and compared to U_α which is selected at "α" or the larger "α" if scored as a range. U_o must be less than U_α to state with some confidence probability greater than 90% that the concentrations at the two sample points differ. Where a single number is listed beneath columns U_o and U_α a probability was computed to compare directly with "α" to determine the confidence probability.

indicate that during the sampling period, concentrations greater than 0 organisms/ml were almost nonexistent at the influent sampling location. However, phytoplankton densities at the prechlorination and postchlorination sampling locations show a distinct growth period from 7/21/76 to 8/08/76 (Table B-1).

The Mann-Whitney 'U' Test was used to determine the significance of the difference in phytoplankton densities between influent and prechlorinated effluent sampling locations, and effluent before and after postchlorination. Concentration differences in both cases have less than a 90 percent probability of occurring. Furthermore, in comparing values of U_0 and U_a, it is evident that confidence probabilities are substantially less than 90 percent in all cases.

The USPHS has set no limits upon algae density. Algae principally degrade water quality by causing taste and odor problems, or increased turbidity if present in large numbers. Several complaints of discolored water and unpleasant odors were received by the Pittsburgh Water Department during late July and early August.

Special Sampling Program

Total organic carbon - Both influent and effluent measurements of total organic carbon (TOC) generally follow the same yearly trend of higher concentrations in late August and during September (Table V-20).

Concentrations of TOC usually decrease from influent to effluent. Approximately 67 percent of the TOC measurements indicate lower concentrations at the effluent location than occur at the influent station. Both increases and decreases in concentration average about 14 percent during the sampling period.

No limits have been set for TOC by the USPHS. Total organic carbon is a gross measure of organic carbon present in the water and usually reflects specific organic parameters such as phytoplankton, and various forms of organic solids.

Trace metals - Analysis for trace metals was basically performed on metals which have proven to be deleterious to health. Measurements of trace metals are listed in Table V-21. In Table V-21, minimum limits of detection, denoted by an asterisk, may change for a given parameter because of using different minimum concentration standards in the atomic absorption analytical technique used.

All measurements of barium are less than or equal to the lower limit of analytical detection except for one effluent measurement on 3/03/75. Virtually no difference in concentration occurs at either the influent or effluent sampling station during the sampling period. The USPHS has set a maximum limit of 1.0 mg/l with which all measurements comply.

TABLE V-20

TOTAL ORGANIC CARBON SAMPLING RESULTS FOR HIGHLAND RESERVOIR NO. 1 , PITTSBURGH, PA.

Date Sample Collected	Total Organic Carbon (mg/l)	
	Influent	Effluent
3/21/75	1.87	1.29
3/31/75	1.36	1.35
4/8/75	1.53	1.37
4/11/75	1.53	1.39
4/18/75	1.01	0.86
4/25/75	1.31	0.92
5/02/75	1.28	1.25
5/11/75	1.31	1.23
5/20/75	1.17	1.34
5/23/75	1.27	0.99
5/30/75	1.24	0.97
6/06/75	1.19	1.10
6/20/75	1.63	1.34
6/26/75	1.70	1.85
7/11/75	1.76	1.40
8/01/75	1.55	1.53
8/08/75	1.35	1.44
8/15/75	1.62	1.53
8/22/75	1.73	1.78
8/29/75	1.81	1.53

Date Sample Collected	Total Organic Carbon (mg/l)	
	Influent	Effluent
9/05/75	2.55	1.86
9/12/75	2.65	2.26
9/19/75	1.76	1.77
9/26/75	1.76	1.51
10/03/75	1.21	1.23
10/10/75	1.04	1.56
10/17/75	1.02	1.03
10/24/75	1.90	1.74
10/31/75	1.37	1.41
11/07/75	0.79	1.18
11/14/75	0.76	0.74
11/21/75	1.63	1.33
11/28/75	1.25	1.08
12/05/75	1.06	1.38
12/12/75	1.87	1.75
12/19/75	1.40	1.39
12/26/75	1.41	1.48
1/16/76	0.98	1.13
1/23/76	1.87	1.58
1/30/76	1.85	1.40

Note: (1) See Figure V-2 for location of sampling sites.

TABLE [illegible]

TRACE METAL SAMPLING RESULTS

FOR [illegible] RESERVOIR NO. 1

Date of Sample Collection	Trace Metals (mg/l)[1]									
	Barium		Chromium		Silver		Copper		Manganese	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	—	[illegible]	—	[illegible]	—	[illegible]	—	[illegible]	—

* Concentration is less than the indicated value

Note: [1] See Figure [illegible] for location of sampling sites.

TABLE [illegible] (Cont)

TRACE METAL SAMPLING RESULTS

[illegible]

Date of Sample Collection	Trace Metals (mg/l)									
	Lead		Iron		Cadmium		Zinc		Mercury	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	—	[illegible]	—	[illegible]	—	[illegible]	—	[illegible]	—

*Concentration is less than or equal to the indicated value.

Note (1) See Figure [illegible] for location of sampling sites.

Chromium concentrations are the same at both sample stations during the year. All measurements are less than or equal to the minimum limit of analytical detection. A maximum limit of 0.05 mg/l for hexavalent chromium was set by the USPHS. The atomic absorption analytical technique used in this study measures total chromium. The USPHS limit is met because all values of total chromium are less than 0.05 mg/l.

Every measurement of silver is less than or equal to the lower limit of analytical detection. Even though the concentrations in Table V-21 change during the year at both influent and effluent sample stations, all silver values may actually be the same as the lowest value (0.01 mg/l). This is possibility is irresolvable owing to limitations of the analytical technique. Silver concentrations do not change from influent to effluent for a particular sample date. USPHS Drinking Water Standards limit silver concentration to 0.05 mg/l. All silver measurements in Highland Reservoir are less than this limit except those during the months of July and August whose compliance with the standard is not known owing to the large magnitude of the lower limit of detection.

Influent and effluent concentrations of copper generally increase from winter to summer during the sampling period. No trend can be discerned from measurements after summer because most concentrations are equal to or less than the minimum limit of analytical detection. Spatial change between influent and effluent is negligible.

Comparison of the copper analytical results in Table V-21 and results from the routine sampling program in Table B-1 (Appendix) indicate different concentrations for both influent and effluent on almost every sample date. The greatest difference (of values greater than the limit of detection) occurs at the influent station (0.14 mg/l) on 1 July 1975 and at the effluent station (0.410 mg/l) on 1 August 1975. The USPHS has recommended the limit on copper to be 1.0 mg/l which is not violated by any of the analytical results.

Both influent and effluent concentration of manganese are fairly erratic during the sampling period. No particular trend of concentration change between influent and effluent sampling stations is discernible. The USPHS has recommended a limit of 0.0 mg/l for manganese. All reported concentrations are less than this standard except during April (0.05 mg/l) at the influent station.

Most concentrations of lead are less than or equal to the minimum limit of analytical detection. This low resolution in concentration definition prevents temporal or spatial evaluation of concentration change. Comparison of the lead analytical results in Table V-21 (greater than the limit of detection and results from the routine sampling program in Table B-1 (Appendix) indicate that results of the routine program are all less than the special trace metal program by 0.011 to 0.049 mg/l.

The USPHS has set a limit on lead concentrations of 0.05 mg/l which is exceeded by one effluent measurement of 0.070 mg/l on 5/01/75. The effluent lead concentration measured in the routine sampling program on 5/01/75 (Table B-1) is 0.037 mg/l. The concentration of 0.037 mg/l is a measurement consistent with other lead concentrations of the routine sampling program measured during May and June. The value of 0.037 mg/l (which is less than the USPHS limit) is probably more representative of effluent lead concentration on 5/01/75 than the value of 0.070 mg/l.

Measurements of iron for both influent and effluent are generally erratic during the sampling period. However, effluent concentrations usually follow the same change in magnitude that influent concentrations display even though effluent values tend to be slightly less than influent values. The Drinking Water Standards of the USPHS recommend a limit of 0.3 mg/l for iron. All measurements of iron in Highland Reservoir are less than this limit.

All measurements of cadmium at both influent and effluent sampling stations are less than or equal to the lower limit of detection, 0.002 mg/l, thus showing no temporal or spatial change. The USPHS has set a limit of 0.01 mg/l on cadmium concentration. No measurement of cadmium in Highland Reservoir exceeds this limit.

Of the zinc concentrations greater than the limit of detection (Table V-21), a slight yearly trend of decreasing influent values is discernible from February to June. Effluent values follow no discernible yearly trend. No spatial trend of concentration change is apparent from influent to effluent sampling stations. The USPHS limits the concentration of zinc in drinking water to 5 mg/l. All measurements of zinc comply with this mandatory limit.

Every concentration of mercury at both influent and effluent sampling stations is less than or equal to the minimum limit of detection (0.0005 mg/l). No limit upon mercury has been set by the USPHS. A general maximum criterion is approximately 0.005 mg/l with which all mercury concentrations in Highland Reservoir comply.

Radiochemical isotopes - Radiation from radioactive substances in domestic water supplies is harmful to human health. The principal criteria by which radioactivity of domestic water is judged are: (1) alpha emitters, specifically, radium isotope 226 (Ra-226); and (2) beta emitters, both gross beta emitters and, specifically, strontium isotope 90 (Sr-90). Alpha particles have low body penetration but are highly dangerous when ingested and deposited within the body. Beta particles have moderate body penetration and are moderately harmful. Occasionally gamma radiation is monitored in water supplies but even though gamma rays are deeply penetrating, they are relatively less damaging than alpha or beta particles.

Radioactivity sampling results for Highland Reservoir No. 1 are presented in Table V-22. Total solids were measured along with radioactivity to indicate the amount of solids in the water which may in part be responsible for measured radioactivity. The total solids results are about 32 mg/l (16 percent) greater than the results of the routine sampling program (see Appendix, Table B-1).

The USPHS Drinking Water Standards set the following maximum limits on radioactivity:

(1) gross beta - 1,000 picoCurie/l (pCi/l);
(2) Sr-90 - 10 pCi/l; and
(3) Ra-226 - 3 pCi/l.

All measurements of gross beta radiation are much less than the 1,000 pCi/l USPHS limit and no trend of change between influent and effluent is apparent. The only measurements of Sr-90 and Ra-226 were made at the influent sampling station on 2/17/75 and 3/04/75. Measurements of Sr-90 and Ra-226 are less than the USPHS limits of 10 pCi/l and 3 pCi/l, respectively. All measurements of gross alpha radioactivity are less than the minimum limit of detection and are less than the USPHS limit of 3 pCi/l for the more specific alpha emitter, Ra-226, indicating acceptable levels. Measurements of specific gamma radiation are all below the minimum limit of detection.

Microbe sampling - Results of water analysis for cytopathic (i.e., harmful to body cells) viruses and coliform bacteria for Highland Reservoir No. 1 are presented in Table IV-19 of Chapter IV. Microscopic examinations of cell cultures for cytopathic effects from concentrate of Highland Reservoir water samples are negative.

Measurements of total and fecal coliform bacteria indicate that these bacteria are essentially absent.

Characterization Studies

Water quality and benthos survey - A survey of water temperature and dissolved oxygen (DO) at various depths was performed on 25 August 1975 to observe any existing thermal stratification. Thermal stratification is caused by the occurrence of different densities of surficial waters and deeper waters. Once stratification is initiated, mixing of deeper and surface waters becomes difficult and the density interface (thermocline) becomes stable. A state of stable stratification is characterized by stagnant water below the thermocline having low levels of DO and temperature, as well mixed water above the thermocline having dramatically higher levels of DO and temperature.

Highland Reservoir No. 1 is an artificial basin with a generally uniform depth of about 6 m. (20 ft). Under natural conditions, this lake could become stratified by late summer. However, a depth of 6 m.

TABLE V-22

RADIOACTIVITY SAMPLING RESULTS FOR HIGHLAND RESERVOIR NO. 1, PITTSBURGH, PA.

Date Sample Collected	Sample[4] Site Location	Date Sample Counted	Total Solids mg/l	Activity (picoCurie/ml)[1]				
				Gross[2] Beta	Gross[3] Alpha	Sr-90	Ra-226	Specific Gamma
2/17/75	Influent	-	246.0	3.2 ± 48%	<2.0	<0.5	0.11 ± 34%	Not Detectable
3/04/75	Influent	-	266.0	2.4 ± 47%	<2.0	<0.5	0.11 ± 34%	Not Detectable
5/01/75	Influent	5/15/75	252.0	2.1 ± 48%	<2.0	-	-	Not Detectable
5/01/75	Effluent	5/15/75	200.0	3.5 ± 34%	<2.0	-	-	Not Detectable
8/01/75	Influent	8/08/75	307.4	4.3 ± 28%	<2.0	-	-	Not Detectable
8/01/75	Effluent	8/08/75	288.0	3.7 ± 31%	<2.0	-	-	Not Detectable
11/01/75	Influent	11/20/75	180.0	1.5 ± 76%	<2.0	-	-	Not Detectable
11/01/75	Effluent	11/20/75	166.0	2.4 ± 42%	<2.0	-	-	Not Detectable

Note: (1) The error expressed is the percentage relative to 2-Sigma counting error.

(2) The minimum detectable limit of gross Beta is 1.0 pCi/l.

(3) The minimum detectable limit of gross Alpha is 2.0 pCi/l.

(4) See Figure V-2 for location of sample sites.

(20 ft) is sufficiently shallow to allow water mixing by wind. Furthermore, Highland Reservoir has an annual average flow of 110,000 cu.m./d (29.1 million gallons per day) which provides a strong mixing influence.

The water quality survey used for sampling stations located in widely separated areas of Highland Reservoir (labeled as benthic sampling stations H-A, H-B, H-C, and H-D in Figure V-2). Measurements of temperature and DO for each of the sampling stations are presented in Table V-23. Water temperature at all four sampling stations show only slight temperature changes from surface to bottom. The following total temperature changes occur at each station: H-A, 0.5°C; H-B, 0.7°C, H-C, 0.6°C; and H-D, 0.2°C. Measurements were made during late morning, with a moderate breeze present. Sampling started at H-D and finished (in reverse alphabetical order) at H-A. The shallow water depth, wind, and flow patterns probably caused water mixing from surface to bottom which may explain the uniform water temperatures in the reservoir. The absence of a thermocline is indicated by the lack of abrupt changes in temperature with depth. Concentrations of dissolved oxygen typically increase slightly from surface to bottom. This trend of DO concentrations is probably due to the photosynthetic production of oxygen by the algal mat that grows on the reservoir bottom. The water column is hypersaturated with oxygen. Greatest hypersaturation occurs near the bottom where oxygen may be produced by algae and less hypersaturation near the surface where oxygen may reach equilibrium most readily.

The following DO changes occur at each station: H-A, 0.3 mg/l; H-B, 0.3 mg/l; H-C, 0.2 mg/l; and H-D 0.1 mg/l. No dramatic change of DO concentrations occur which further substantiates the absence of a thermocline.

Neither measurements of temperature nor dissolved oxygen provide evidence indicating that stratification existed in Highland Reservoir No. 1 on 25 August 1975.

Part of the water quality and benthos survey included a qualitative survey of benthic organisms at the six sampling stations shown in Figure V-2. Results of the benthos survey are presented in Table V-24. Sample stations H-A, H-B, H-C, and H-D are at the same locations as the stations of DO and temperature measurement discussed previously. Two additional benthic sampling stations located at increasingly shallow depths provide information concerning the types of microorganisms of reservoir bottoms with respect to different depths. All of the organisms listed in Table V-24 are algae which have settled to the bottom. All of these algae are diatoms.

The spatial location of the various forms of algae is probably not significant owing to variable water currents and floating properties of the algae which disperse them.

TABLE V-23

TEMPERATURE-DISSOLVED OXYGEN WATER COLUMN PROFILES OF HIGHLAND RESERVOIR NO. 1

Reservoir Depth (ft.)[3]	Sample Sites[1][2]							
	H-A		H-B		H-C		H-D	
	Temper-ature (°C)	Dissolved Oxygen (ppm)	Temper-ature (°C)	Dissolved Oxygen (ppm)	Temper-ature (°C)	Dissolved Oxygen (ppm)	Temper-ature (°C)	Dissolved Oxygen (ppm)
0	24.5	8.7	24.3	8.8	24.6	8.9	24.3	8.8
5	24.4	9.0	24.5	8.8	24.2	8.9	24.1	8.8
10	24.2	8.9	24.2	8.7	24.0	9.0	24.1	8.9
15	24.0	9.0	24.1	9.0	24.0	9.1	24.2	8.9
20	24.0	9.0	24.1	9.6	24.0	9.1	24.1	8.9

Note:

(1) All of these measurements were made during late morning of 25 August 1975.
(2) See Figure V-2 for location of sample sites (which are included with the benthic sampling sites).
(3) One foot = 0.305 m.

TABLE V-24

DELINEATION OF BENTHIC MICRO-ORGANISMS INHABITING HIGHLAND RESERVOIR NO. 1, PITTSBURGH, PA.

Name of Organism	Benthic Sample Sites[1]				
	H-A	H-B	H-C	H-D	H-E
Diatoma sp.					
Pinnularia nobilis	X	X	X	X	X
Rhopalodia gibba	X	X	X	X	X
Surirella sp.	X	X	X	X	X
Synedra ulna	X	X		X	X
Cocconeis sp.	X			X	X
Cymbella sp.	X	X	X	X	X
Navicula sp.	X	X		X	X
Fragilaria sp.					X
Nitschia sigmoidea					
Ulothrix sp.					
Cymatopleura solea					
Tabellaria fenestra					
Stephanodiscus sp.					
Asterionella sp.					
Ulothrix sp.					
Zygnema sp.					
Enococconeis flex					
Eunotia sp.					
Rotifer sp.					

Note: (1) See Figure V-2 for location of sample sites.

Dustfall sampling - The amount of airborne particulates settling on Highland Reservoir No. 1 was measured from March, 1975 to January, 1976. Results of this sampling program are presented by sampling location on a unit basis in Table V-25. The two sampling stations are near one another in the larger of the two reservoir basins (stations DH-1 and DH-2; Figure V-2). A typical dustfall value is about 7.8 g/sq.m. (70 lb/acre) per standard 30 day month. If this amount of solids is suspended in the entire volume of the reservoir, 500,000 cu.m. (131 million gallons), during a 4.5 day time period (theoretical reservoir detention time) the result is a suspended solids concentration of 0.2 micrograms/liter. A typical influent or effluent suspended solids concentration (total solids minus dissolved solids) is about 3 mg/l indicated by the routine sampling program. The hypothetical dustfall suspended solids concentration of the reservoir (0.2 ug/l) is an negligible 0.007 percent of the existing reservoir suspended solids concentration (3 mg/l). Thus, by removing one source of potential suspended solids, the dustfall sampling program suggests that most of the suspended solids which are present in the reservoir are due to influent concentrations.

Hydraulics of Highland Reservoir No. 1 - The annual, average flow through Highland Reservoir No. 1 is 110,000 cu.m./d (29.1 mgd) during the study period (February, 1975 - January, 1976). For lack of reliable metered effluent flow data, the gain or loss of water (other than system flows) from the reservoir can not be calculated with reasonable accuracy.

Highland Reservoir has a total capacity of approximately 500,000 cu.m. (130 million gallons). The theoretical detention time is 4.5 days. The actual detention time is probably less than the theoretical detention time due to the lack of baffles and subsequent flow short-circuiting between inlet and outlet.

Summary of Data Evaluation

Routine Sampling Program

Most of the water quality parameters in the routine sampling program (Table V-26) indicate some pattern of change during the sampling period; exceptions are pH, apparent color, copper, nitrate, total phosphate, soluble orthophosphate, total orthophosphate, and total coliforms.

The following parameters showed general increases or decreases in concentration between influent and effluent sampling locations:

General Increase	General Decrease
Lead	Temperature
Total Standard Plate Count	Total Chlorine Residual
Phytoplankton	Free Chlorine Residual

TABLE V-25

DUSTFALL SAMPLING RESULTS FOR HIGHLAND RESERVOIR NO. 1, PITTSBURGH, PA.

Month of Collection	Dustfall Data (lb/acre)(1)	
	Site DH-1	Site DH-2
March, 1975	44	-
April	91	103
May	75	38
June	72	63
July	63	56
August	78	-
September	266	-
October	69	59
November	69	73
December	175	-
January, 1976	-	-

Note: (1) See Figure V-2 for location of sampling station.

(2) 1 lb/acre = 112 mg/sq.m.

TABLE V-25

PATTERNS OF WATER QUALITY CHANGE AND COMPLIANCE WITH WATER QUALITY STANDARDS
ROUTINE SAMPLING PROGRAM—HIGHLAND RESERVOIR NO. 1

Water Quality Parameters	Changes in Concentration				Compliance w/Standards U.S. Public Health Service Drinking Water Standards (1962)	
	Time-related Changes —	Change Between Sampling Stations				
		Increased In Effluent	Decreased In Effluent	Mixed Patterns of Change	Required	Recommended
Temperature	Yes	No	Yes	No	—	—
pH	No	No	No	No	—	—
Apparent Color	No	No	No	No	Yes	—
Turbidity	Yes	No	No	Yes	Yes	—
Total Solids	Yes	No	No	No	—	—
Dissolved Solids	Yes	No	No	No	—	—
Total Alkalinity	Yes	No	No	No	—	—
Total Hardness	Yes	No	No	No	—	—
Total Chlorine	Yes	No	Yes	No	—	—
Residual Chlorine	Yes	No	Yes	No	—	—
Copper	No	No	No	No	—	—
Lead	Yes	Yes	No	No	—	—
Ammonia	Yes	No	No	No	Yes	—
Nitrate	No	No	No	No	—	—
Total Phosphate	No	No	No	No	—	—
Soluble Ortho-phosphate	No	No	No	No	—	—
Total Ortho-phosphate	No	No	No	No	—	—
Total Coliforms	No	No	No	No	Yes	—
Total Standard Plate Count	Yes	Yes	No	No	—	—
Phytoplankton	Yes	Yes	No	No	—	—

Turbidity showed both increases and decreases at different times during the study.

The 1962 U.S. Public Health Service Drinking Water Standards were met in all cases. However, levels of two parameters, temperature and ammonia, do not meet on occasion other criteria (see previous discussion in this Chapter under Results of Data Evaluation) of desirable water quality. The concentrations observed do not appear to be of concern.

Special Sampling Program

Total organic carbon (TOC) - Both influent and effluent concentrations of TOC generally follow the same yearly trend although effluent values are typically lower than influent values.

No limit of TOC has been set by the USPHS, however, all concentrations of TOC are generally low.

Trace metals - All of the metals analysed were within the limits of the 1962 USPHS standards except for one measurement of lead. Most of the data could not be analysed because most of the observed concentrations were equal to or below the analytical limit detection. Mercury is not included in the USPHS standards, but observed concentrations were less than generally accepted safe concentrations.

Of the ten trace metals measured, only copper and zinc show a yearly pattern of change. None of the trace metals except iron change in concentration between sampling stations. Iron values show a slight decrease from influent to effluent.

Radiochemical isotopes - The following parameters were measured at influent and effluent locations of Highland Reserovir as indicators of radioactive contaminants; gross beta particles, gross alpha particles, strontium-90 (Sr-90), radium-226 (Ra-226), and specific gamma radiation.

None of the results from analysis of the parameters indicate patterns of change during the sampling period or change in value between sampling stations.

The USPHS has set drinking water standards for gross beta particles, Sr-90, and Ra-226. All measurements of these three parameters are less than the USPHS standards. Measurements of gross alpha particles and specific gamma radiation are less than generally accepted criteria.

Microbe sampling - Results of Highland Reserovir analysis for cytopathic viruses were negative. Water analysis for total and fecal coliform bacteria indicated that these bacteria were essentially nondetectable.

Characterization Studies

Water quality and benthos - On 25 August 1975, measurements of temperature and dissolved oxygen (DO) were performed at regular intervals of depth, at four locations in Highland Reservoir No. 1. Results of this sampling indicate only slight changes in temperature and DO from surface to bottom. The small change that does occur shows a typical rapid decrease in temperature near the surface with a much slower decrease near the bottom. Concentrations of DO increase slightly from surface to bottom. Neither measurements of temperature nor DO provide evidence of stratification existing in Highland Reservoir.

A qualitative survey of benthic microorganisms was performed on 25 August at six locations in Highland Reservoir No. 1. All of the eight organisms identified were species of diatoms (algae). Most of these diatoms had probably settled to the bottom from upper depths.

Dustfall sampling - Results from measuring dustfall at two locations at Highland Reservoir No. 1 indicate a typical value of about 7.8 g/sq.m. (70 lb/acre) per month. If dustfall were to account for the suspended solids concentration in the reservoir then the concentration would be about 0.2 mg/l instead of the typical suspended solids concentration of 3 mg/l indicated by results of the routine sampling program. Consequently, dustfall was not a significant contributing factor to the suspended solids concentration in the reservoir.

Hydraulics of Highland Reservoir No. 1 - The annual average flow of water through Highland Reservoir No. 1 was about 110,000 cu.m./d. (29.1 mgd) during the study period (February, 1975 - January, 1976). The theoretical detention time was 4.5 days.

ALTERNATIVE WATER QUALITY CONTROL MEASURES

Introduction

A clearly desirable objective of water system operation is the maintenance of water quality throughout the system from the treatment plant to the consumer's tap. However, storage of water to meet peak consumer demands is usually necessary, and this portion of the system is usually where the greatest potential for water quality degradation occurs.

Previously discussed possible sources or causes of water quality degradation in Highland Reservoir No. 1 include:

- airborne particulates
- surface runoff
- groundwater

- unauthorized human contact

- weather

- biological processes in the reservoir

Water quality control measures for treated water reservoirs may be categorized as (1) measures to prevent contamination or the development of undesirable condition, and (2) measures to correct such conditions after they have occurred. Both types of control measures may involve construction of facilities or the use of operation and maintenance procedures. Ultimately, these measures will be used to develop alternatives for controlling degradation of the finished water in Highland Reservoir No. 1.

Preventive Control Measures

The potential control measures which can prevent the water quality of Highland Reservoir No. 1 from being degraded to some degree by one or more of the above mentioned sources include covering the reservoir, bottom lining of the reservoir, proper grading and design of the reservoir site to prevent entry of surface runoff, and establishment of proper security measures such as physical barriers and patrols. The reader is referred to Chapter IV for an explantion of the reasons why preventive measures are preferable in many cases to corrective measures for control of reservoir water quality.

Reservoir Covers

Two types of reservoir covers to be considered for Highland Reservoir No. 1 are rigid covers and floating covers.

Rigid cover - Because of the fairly large size of Highland Reservoir No. 1, 8 ha. (21 acres), only two types of rigid covers were considered - a plywood roof and a precast concrete roof.

The plywood roof would be constructed of plywood sheets supported on glue-laminated purlins and griders which would be supported on precast columns and a peripheral wall. This cover was eliminated from consideration for an alternative because of wood preservative loss by condensate from the underside of the roof dripping into the water. The wood preservative chemicals may cause taste and odor problems and may provide a nutrient source for bacterial growth (see subsection-Rigid Reservoir Cover of Chapter IV). Furthermore, the loss of wood preservative results in additional periodic maintenance costs during the 25-30 year expected life of the cover.

A concrete cover would consist of precast reinforced concrete slabs supported by integral concrete beams which rest upon interior reinforced concrete columns and a perimeter shear wall. Such a cover provides a roof and side walls which minimize contact with the ambient environment and is effective in excluding contaminants from the reservoir when properly maintained and operated.

Several common operation and maintenance procedures include: (1) ventilation openings in the cover must be periodically cleaned of debris; (2) manholes must be free of obstructions; (3) water tight seals of the roof must be maintained; and (4) water which might collect on the roof must be drained. A concrete cover is rigid which means that the cover will remain in place if the reservoir must be drained for inspection and/or repair work on the bottom.

The environmental impact of a concrete cover over Highland Reservoir is principally concerned with detracting from the visual aesthetic nature of the surrounding Highland Park area. The open water of the reservoir is probably more attractive than an expanse of concrete. Citizens of Pittsburgh that frequent the park have demonstrated their concern for maintaining the attractiveness and accessibility of the reservoir as it currently exists. In 1972, the reservoir was to be protected from public access by construction of a fence. Because of public protest, including the petitioning of the Pittsburgh City Council, construction of the proposed fence was never initiated. However, a concrete cover could be designed to provide a suitable surface for uses such as tennis courts, automobile parking, or it may even be landscaped to fit into the park or roof as an artificial lake.

The estimated construction cost (1976) of a concrete cover for Highland Reservoir is about $7 million based on a preliminary design that would support uses such as automobile parking and tennis courts. This figure should be added to other costs (legal, administrative and engineering; about 25 percent) and an allowance for contingencies (15 percent) for a preliminary estimate of around $10 million total cost.

This cost is considered conservative (within the assumptions made) and it might be reduced somewhat by careful analysis of design alternatives. On the other hand, other desired uses such as extensive landscaping with soil or sod might result in some increase in cost.

Flexible floating cover - A flexible floating cover consists of an elastomeric sheet stretched over the reservoir's water, support by foam floats, and attached to a peripheral concrete foundations. The cover rises and falls with the water level and is sloped from the center to the perimeter causing rain water to drain and collect near the outside where it is pumped out. When properly maintained and operated, the cover protects reservoir water quality as does the concrete cover.

While operation of Highland Reservoir No. 1 with a floating cover would be similar to operation under a rigid cover, the costs of operation and maintenance would probably be less owing to the simplicity of the floating cover system. However, inspection and repair of the bottom including sediment removal would be more difficult with a floating cover. Work must be performed underwater because the cover would fall to the bottom if the reservoir were drained.

The principal components of a floating cover for Highland Reservoir No. 1 are: (1) elastomeric material and foam floats; (2) anchorage foundation around the reservoir perimeter; and (3) a pump/siphon system to remove surface water. While several types of elastomeric materials are available for use as covers, the material considered best for Highland Reservoir is composed of chlorosulfonated polyethylene (Hypalon, DuPont), a synthetic rubber, reinforced with nylon. The useful life of a cover made of this material is 20 to 40 years.

Estimated construction costs (1976) for installation of the floating cover system on Highland Reservoir ranges from about $0.9 million to $1.6 million, with the higher cost probably being more realistic. The total cost (including other costs and contingency allowance) would be about $2.2 million.

The principal environmental effect of installing a floating cover on Highland Reservoir No. 1 is that the reservoir would be visually unattractive as in the case of a concrete cover. Unlike a concrete cover, however, a floating cover provides no other use than protecting the water of Highland Reservoir No. 1.

Reservoir Bottom Lining

An impermeable lining on the bottom of a finished water reservoir will prevent water leakage from the basin and will also prevent the infiltration of groundwater and associated dissolved solids into the reservoir. Refer to the subsection concerning Reservoir Bottom Lining in Chapter IV for a description of types of linings available.

Only linings made of plastic or synthetic rubber are considered to be feasible for Highland Reservoir No. 1 because of the high cost of the other types of liners and the large surface area of the reservoir to be lined. The types of plastic and synthetic rubber linings considered for Highland Reservoir are the following: plastic-polyvinyl chloride (PVC), ethylene propylenediene monomer (EPDM), and chlorinated polyethylene (CPE), synthetic rubber-butyl rubber, and chlorosulfonated polyethylene (Hypalon, DuPont). Manufacturers' minimum projections of life expectancy are about 40 years for all of these liners when properly installed and maintained. Actual use of these materials has been met with varying amounts of success and no particular one will be recommended.

A survey of installation costs for lining Highland Reservoir No. 1 indicates the following prices:

Hypalon (nylon reinforced) = $419,000 - $699,000
EPDM (nylon reinforced) = $587,000 - $932,000
Butyl rubber = $419,000
CPE (nylon reinforced) = $419,000 - $466,000
PVC (nylon reinforced) = $326,000

The presence of a membrane liner in Highland Reservoir No. 1 may make the reservoir less attractive because of a synthetic shoreline being exposed rather than a natural appearing shoreline.

Surface Runoff Diversion

Erosion products from surrounding paved and unpaved areas of a finished water reservoir have the potential of being carried by rain or snowmelt surface runoff into the reservoir. Accumulation of contaminants on paved areas between rainstorms causes the first flush of rain runoff from a storm to possess high concentrations of pollutants. Surface runoff may increase reservoir concentrations of phosphorus, nitrogen, organics, suspended solids, zinc, and lead. During winter, surface runoff of de-icing compounds may increase concentrations of dissolved solids from the presence of sodium chloride and/or calcium chloride.

Surface runoff of erosion products does not present a significant source of contaminants to Highland Reservoir No. 1. The reservoir is surrounded by a 0.3 m. (1 ft) high parapet wall. This wall plus the high sloping banks which drain away from the reservoir practically eliminates the possibility of surface runoff contamination.

Security Establishment and Maintenance

To preserve the high quality of water in a finished water reservoir, people must not be allowed to swim or otherwise have contact with the water or to throw objects into the water. Reservoir security may be established and maintained by the presence of a physical barrier such as a perimeter fence and existence of a security patrol.

Highland Reservoir No. 1 is not protected from public access. People that walk near the water's edge are constrained from falling into the water by a rail fence about 1.2 m. (4 ft.) high that surrounds the reservoir. Signs describing the use of the water and warnings against contamination are posted around the perimeter. In 1973, the reservoir was to be protected from public access by construction of a fence. Because of public protest, including the petitioning of the Pittsburgh City Council, construction of the proposed fence was never initiated.

Prevention of contaminant deposition by illegal entry to the reservoir is accomplished by periodic surveillance. Surveillance is provided by the Pittsburgh Police Department once every hour (24 hr. day) the Pittsburgh Park Police sporadically, and a civilian patrol consisting of volunteer walkers who will report security violations to police. Employees of the Water Department also provide security during their activities concerning operation of the reservoir.

To ensure for more effective reservoir security it is recommended that a fence be constructed to protect the existing open reservoir from public access. The proposed fence should have the product of fence height and reservoir setback (expressed in feet) of at least 600 (Ref. V-3). This could be accomplished by building a six foot fence 100 feet from the perimeter of the reservoir. The estimated construction cost for installation of this fence (approximately 4,770 lineal feet) is $70,000 for Highland Reservoir No. 1.

Other possible security improvements the costs of which will not be considered in the following analysis of alternatives are that a more intense formal surveillance system should be initiated, and that a formal emergency plan should be established for immediate isolation of the reservoir from the distribution system if the water is believed to be contaminated.

Corrective Control Measures

The various measures available to correct or improve water quality conditions in Highland Reservoir No. 1 that occur as a result of one or more of the previously discussed sources of degradation primarily involve post-reservoir treatment, operational changes, modified maintenance, and a proper monitoring program. The nature and extent of these corrective measures for Highland Reservoir No. 1 will be based on the results of the extensive sampling and characterization programs. Only the measures (both the existing measures being implemented and any additional measures) to correct identified problems will be evaluated.

In order to assure adequate post-reservoir disinfection and pathogen deactivation additional chlorine contact time should be provided directly following chlorination of the reservoir effluent. Also, regular addition of copper sulfate and calcium hypochlorite (HTH) to control algae growth and other microorganisms that cause taste and odor should be practiced. Programs to control growth of shore plants should be continued. The existing water quality monitoring program at Highland Reservoir No. 1 appears to be adequate relative to insuring that the water will meet the 1962 USPHS Standards. Additional monitoring may be warranted, but will not be pursued further in this report.

The following discussion will summarize the necessary corrective measures required at Highland Reservoir No. 1 to maintain the quality of the water delivered to the consumer. Specific water quality parameters affected include: bacteria (e.g., coliforms), viruses, phytoplankton, organic compounds (including constituents-carbon, nitrogen, and phosphorus compounds) copper, chlorine/chlorine compounds, turbidity, color, solids, taste and odor.

Chlorine Disinfection

Chlorine disinfection is presently used in operation of Highland Reservoir No. 1 to control pathogenic organisms. Reservoir influent only receives chlorination at the Pittsburgh Water Treatment Plant. Chlorination at the treatment plant is designed to maintain a concentration of 1-2 mg/l residual chlorine in plant effluent water. Effluent water from Highland Reservoir receives chlorination at each of the four withdrawal pipelines. Post-reservoir chlorination is intended to insure that water received by consumers in the most distant portions of the distribution system has a residual chlorine concentration of 0.3-0.5 mg/l.

A two-hour reaction time to assure effective post-reservoir disinfection is proposed as an improvement to the existing post-reservoir chlorination facilities. This reaction time will assure effective disinfection without water reaching the consumer with an undesirable concentration of residual chlorine which may be objectionable due to the presence of taste and odors.

A contact basin volume of almost 2.5 million gallons is required. This proposed volume will consist of a rectangular earthen basin which will be lined with an impermeable, butyl neoprene bottom liner and covered with a floating nylon-reinforced, synthetic rubber cover. In this manner, the chlorine contact basin will be effectively isolated from potential sources of contamination while it is being used for disinfection purposes. A basin with an average depth of ten feet will need an area of approximately 0.8 acres. The basin could be located adjacent to the south end of the reservoir where most of the effluent piping is located. This would minimize the need to rearrange existing piping. Also, the existing reservoir postchlorination facilities could be relocated appropriately and continue to be used. The same amounts of chlorine that are presently being applied will be injected into the effluent prior to the contact basin for proper mixing.

Post-reservoir chlorination facilities are now centralized at one station. Part of the facilities present in the station is a chlorine control manifold which regulates the flow of chlorine from four, 68 kg (150 lb) cylinders to two chlorinators. One of the two chlorinators is a 180 kg (400 lb) machine that feeds two effluent water pipelines (the two effluent lines with sampling stations H-6 and H-7; Figure V-1) via two chlorine lines. Equal amounts of chlorine go to each chlorination point. The remaining chlorinator in the chlorination station is a

900 kg (200 lb) machine that feeds the two remaining effluent water pipelines (located in Figure V-1 by sampling stations H-2 and H-4) via two chlorine lines. Equal amounts of chlorine go to each chlorination point. Chlorine feed rate is set manually for each machine based on results from the system water quality monitoring program (see Chapter II).

The capital costs for the construction of the chlorine contact basin including bottom lining, floating cover, additional piping, other miscellaneous costs, and contingencies are approximately $200,000.

Chlorination of effluent from Highland Reservoir No. 1 requires about 17 metric tons (18 short tons). During 1975, the total annual cost, at $0.36/kg ($325/ton), was $5,900 per year.

Total labor requirements for chlorination of Highland Reservoir were the following (1975-76):

(1) general servicing and maintenance = 4 hr/wk; and

(2) chlorine cylinder transport = 10 hr/wk.

Total annual labor costs are about $4,600 per year. Total annual operating costs of chlorination for Highland Reservoir No. 1 are approximately $10,500 per year.

Results from the routine sampling program of this study suggest that post-reservoir chlorination servicing the two effluent lines with sample stations H-6 and H-7, are inoperative. The change in concentrations of both total chlorine and residual chlorine before and after postchlorination is negligible. This chlorination operation should be made operative if, in fact, it is not working. In addition, greater pre-reservoir chlorination should be implemented to insure a residual chlorine concentration of 1-2 mg/l in the reservoir to prevent bacterial growth. Even with the periodic application of calcium hypochlorite, used as an algacide, all effluent measurements to residual chlorine were less than 0.85 mg/l.

Copper Sulfate and Calcium Hypochlorite Application

The present seasonal program of addition of copper sulfate and calcium hypochlorite does not completely and effectively control the growth of algae in Highland Reservoir No. 1. The periodic applications by hand of copper sulfate and calcium hypochlorite from a small boat to the waters surface should be increased so as to effect a reduction in taste and odor problems that occur, especially in July and August. During 1975, 19 applications of copper sulfate were made of 680 kg (1,500 lb) each. These applications were performed during summer and fall on the following basis: May = 2 applications, once/week for 2 weeks; June = 4 applications, once/week; July = 12 applications, 2/week; August = 12 applications, 3/week; September = 6 applications, 2/week; and October =

3 applications, once/week for 3 weeks. The cost of copper sulfate alone was a total of $15,800/year at $0.60/kg ($540/ton).

During each application of copper sulfate, calcium hypochlorite (HTH) is also applied to control the growth of algae and prevent bacterial growths. Each of the 39 applications of HTH required about 500 kg (1,000 lb). The total cost of HTH during 1975 at $0.76/kg ($34.30/100 lb) was $14,800/yr.

It is recommended that approximately a 27 percent increase in chemical dosages be instituted in association with the necessary increase in labor costs in order to achieve the desired control of algae in Highland Reservoir. The revised total annual operating costs for this program would be as follows:

Copper sulfate costs = $20,000/yr

Calcium hypochlorite = 18,800/yr

Labor = 10,000/yr

Total $48,800/yr

These added costs should result in closer synchronization of chemical applications to the potential situation for increased concentrations of algae that occur during the summer.

Shore Plant Growth Control

Shore plant growth is effectively controlled at Highland Reservoir No. 1 as required by intermittent cutting and removing of weeds. This operation is performed by a team of three men usually once per year working for about a two week period. Total annual cost is approximately $800 per year.

Summary of Corrective Measures

In order to maintain a high quality potable water to be delivered to the consumers the following costs will be incurred by contained operation of an open reservoir at Highland Park. Not included among these corrective measure costs is the cost of construction of a perimeter fence which is considered a preventive measure. The following discussion of alternatives trade-off assessment will bring all these various costs into perspective.

Control Measure	O&M ($/yr)	Capital Cost ($)
Chlorination/Disinfection	$10,000	$200,000
Copper Sulfate/HTH Addition	48,800	
Shore Plant Control	800	
Totals	$59,600/yr	$200,000

Alternatives Trade-off Assessment

The various alternatives available for the maintenance of a high quality potable water supply for the City of Pittsburgh vis-a-vis Highland Reservoir No. 1 involve measures to prevent contamination or development of an undesirable condition in the reservoir, and measures to correct such conditions after they have occurred. In particular, the results of the water sampling program detailed in this report, were used as a basis to develop a set of alternatives comprised of the aforementioned control measures (preventive and/or corrective). These alternatives will serve to mitigate water quality problems and protect Highland Reservoir from sources or causes of this deterioration. The results of the sampling program at the reservoir, however, did not indicate any general deterioration in the potability of the water supply as defined by the 1962 USPHS Drinking Water Standards and other recognized water quality standards. These standards were simply not violated during the study period.

Therefore, the evaluation of alternatives will be based on the relative potential for water quality deterioration that could occur in the reservoir. An important consideration in the development and analysis of alternatives is the possibility that unmeasured water quality parameters could have deteriorated in the open reservoir system even though measured ones did not. This inherent risk in encountering water quality problems in the open Highland Reservoir No. 1 has been translated into a set of general control criteria for the overall preferred management of an open reservoir alternative. The costs and potential benefits associated with alternatives which involve covering the reservoir must then be weighed against the costs associated with the adoption of the preferred open reservoir management alternative and its corresponding degree of mitigation of potential water quality problems and undesirable conditions.

Total costs of an alternative are defined as both the capital and the annual operation and maintenance costs. For the purposes of this analysis, total costs may be expressed as the average annual equivalent cost over a 30 year period so as to represent all of these costs on an equivalent basis. In doing so, capital costs are amortized at a discount rate of six percent. Additionally, annual O&M costs are inflated at a six percent rate over the designated 30 year period, and then averaged.

The alternative, which assumes the preferred management of an open Highland Reservoir No. 1, must incorporate the perimeter fence control measure, as well as all of the previously discussed corrective measures: additional post-reservoir disinfection reaction time, upgraded copper sulfate and calcium hypochlorite addition programs, etc. The total costs of this alternative amount to $176,000 average annual equivalent cost. This cost is comprised of an amortized capitil cost (chlorine contact basin plus perimeter fence) of $19,600 per year and an average O&M cost of $157,000 per year considering inflation. The control measures associated with this alternative will provide for the attainment of the 1962 USPHS Drinking Water Standards, as well as preferred operational procedures, that will lessen the risk of potential water quality contamination. However, potential unidentified contaminants (e.g., asbestos and chloroform) may not be removed or reduced below harmful levels. Also, potential contamination from airborne entry and the loss of residual chlorine in the reservoir with the resultant growth of aquatic microorganisms with the risk of production of toxic compounds could occur.

An alternative incorporating the emplacement of a concrete cover on Highland Reservoir No. 1 would incur an amortized capital cost of $726,900 per year. The average annual O&M costs cannot be estimated; however they are expected to be less than the existing O&M costs experienced for the reservoir. Costs for addition of algae control chemicals would be eliminated and chlorination costs most likely would be reduced. Moreover, a cover would eliminate the risks of encountering potential water quality problems associated with an uncovered reservoir.

The emplacement of a floating cover over Highland Reservoir No. 1 would result in an alternative utilizing a preventive control measure at a reduced cost from a rigid cover alternative. The amortized capital cost of covering Highland Reservoir in this manner is approximately $180,000 per year. The inclusion of a reservoir bottom liner would increase amortized capital costs to approximately $198,000 per year. As with the concrete cover alternative, O&M costs cannot be quantified for the floating cover alternative. No annual costs will be attributed to chemical addition for the control of algae. Annual chlorination costs should be less then presently experienced. There will be some annual costs associated with the maintenance of a floating cover that should also be considered.

The installation of a floating cover appears to be comparable to the open reservoir alternative based on preliminary costs. However, the addition of the annual O&M costs to the amortized capital costs of the floating cover alternative will undoubtedly increase the total costs above those attributable to the open reservoir alternative. Yet, the total costs of a floating cover for Highland Reservoir No. 1 are still in the economic range of consideration. More important is the question of whether the increased cost of a floating cover will be offset by the benefits afforded to the water quality of a covered reservoir. The confidence to maintain a continuous high quality, potable water is greater with the floating cover than with the open reservoir alternative. For example, even though the loss of chlorine residual in the open Highland Reservoir has not resulted in coliform bacteria concentrations which exceed USPHS standards, the covering of the reservoir would prevent the loss of chlorine residual from occurring as rapidly and would insure the prevention of pathogen contamination of the system. However, local residents would probably express a negative reaction towards the covering of the reservoir due to the aesthetic benefits they derive from maintaining the reservoir in its existing open state. Ultimately, all of the costs and benefits, both potential and realized must be detailed before the decision to cover is made.

CHAPTER V

REFERENCES

V-1 *Standard Methods for the Examination of Water and Wastewater*, thirteenth edition, American Public Health Association, Washington, D.C., 1971.

V-2 *Water Quality Criteria*, California State Water Quality Control Board, second edition, 1963.

V-3 *Draft Environmental Impact Statement of Proposed Amendments to State Board of Health Rules and Regulations Regarding Public Water Supplies - WAC 248-54 - The Amendments Relate to Potable Water Distribution Reservoirs*, Office of Environmental Health Programs, Washington State Department of Social and Health Services, April 1975.

APPENDIX

WATER QUALITY DATA FROM ROUTINE WATER SAMPLING PROGRAM

TABLE A-1

WATER QUALITY SAMPLING DATA FOR [illegible] LAKE

[illegible]

TOTAL COLIFORMS [illegible]/100ML			FECAL COLIFORMS [illegible]/100ML			TOTAL STANDARD PLATE COUNT [illegible]/ML			SAMPLE DATE OF I Y M D	SAMPLE DATE OF [illegible] Y M D
I	[illegible]	[illegible]	I	[illegible]	[illegible]	I	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CONTINUED

TABLE A-1

WATER QUALITY SAMPLING DATA FOR [illegible] LAKE

TOTAL COLIFORMS [illegible]/100ML			FECAL COLIFORMS [illegible]/100ML			TOTAL STANDARD PLATE COUNT [illegible]/ML			SAMPLE DATE OF I	SAMPLE DATE OF [illegible]
I	[illegible]	[illegible]	I	[illegible]	[illegible]	I	[illegible]	[illegible]	Y M D	Y M D

CONTINUED

TABLE A-1

WATER QUALITY SAMPLING DATA PER CRUISE LINE

TOTAL COLIFORMS [illegible]/100ML			FECAL COLIFORMS [illegible]/100ML			TOTAL STANDARD PLATE COUNT [illegible]/ML			SAMPLE DATE [illegible]	SAMPLE DATE [illegible]
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TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR DRUID LAKE

TEMPERATURE [illegible]DEG.F		APPARENT COLOR [illegible] UNIT		TURBIDITY [illegible]		FREE CHLORINE [illegible]MG/L		TOTAL CHLORINE [illegible]MG/L		SAMPLE DATE OF I	SAMPLE DATE OF E
I	E	I	E	I	E	I	E	I	E	Y M D	Y M D
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR [illegible] LAKE

TEMPERATURE [illegible]		APPARENT COLOR [illegible] UNIT		TURBIDITY [illegible]		FREE CHLORINE [illegible] MG/L		TOTAL CHLORINE [illegible] MG/L		SAMPLE DATE OF I	SAMPLE DATE OF S
I	S	I	S	I	S	I	S	I	S	Y M D	Y M D
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR DRUID LAKE

TEMPERATURE (DEG.F)		APPARENT COLOR [illegible] UNIT		TURBIDITY [illegible]		FREE CHLORINE [illegible]		TOTAL CHLORINE [illegible]		SAMPLE DATE OF I	SAMPLE DATE OF E
I	E	I	E	I	E	I	E	I	E	Y M D	Y M D
62	63	1.0	1.0	0.26	0.28	4.80	0.01	5.40	0.01	751010	751015
63	61	1.0	1.0	0.31	0.36	2.40	0.05	3.00	0.13	751013	751017
52	63	1.0	1.0	0.67	0.40	3.00	0.01	3.80	0.01	751015	751020
61	59	1.0	1.0	0.29	0.50	2.90	0.01	6.20	0.01	751017	751022
61	63	1.0	1.0	0.79	0.44	3.90	0.31	4.90	0.01	751020	751024
55	61	1.0	1.0	0.51	0.37	4.00	0.01	4.90	0.10	751022	751027
52	61	1.0	1.0	0.25	0.70	4.20	0.20	4.40	0.20	751024	751030
62	61	1.0	1.0	0.84	0.27	3.90	0.10	5.20	0.10	751027	751031
61	60	1.0	1.0	0.25	0.25	4.00	0.01	4.00	0.01	751030	751103
59	60	1.0	1.0	0.17	0.19	4.10	0.01	4.10	0.05	751031	751106
	59	1.0	1.0	0.11	0.18	3.90	0.10	5.90	0.10	751103	751110
60	60	1.0	1.0	0.15	0.21	4.40	0.10	4.50	0.19	751106	751113
55	56	1.0	1.0	0.13	0.26	4.30	0.31	4.30	0.31	751110	751117
59	56	1.0	1.0	0.19	0.23	4.00	0.20	4.00	0.25	751113	751120
55	54	1.0	1.0	0.16	0.26	5.43	0.01	5.40	0.31	751117	751124
57	54	1.0	1.0	0.27	0.28	4.60	0.31	4.40	0.31	751120	751126
	54		1.0		0.26		0.01		0.01	751124	751201
50	50	1.0	1.0	0.13	0.27	3.20	0.01	5.20	0.01	751126	751205
52	58	1.0	1.0	0.25	0.27	4.80	0.01	4.80	0.31	751201	751208
46	48	1.0	1.0	0.16	0.71	4.00	0.10	4.00	0.10	751205	751211
49	51	1.0	1.0	0.23	0.23	4.80	0.01	4.80	0.31	751208	751215
47	46	1.0	1.0	0.19	0.17	5.00	0.01	5.00	0.31	751211	751218
48	49	1.0	1.0	0.16	0.14	5.00	0.31	5.00	0.31	751215	751222
46	41	1.0	1.0	0.15	0.20	3.03	0.10	5.30	0.10	751218	751224
44	42	1.0	1.0	0.12	0.50	7.00	0.01	7.00	0.10	751222	751229
42	42	1.0	1.0	0.60	0.36	7.00	0.01	6.30	0.10	751224	751231
42	50	1.0	1.0	0.32	0.25	5.80		6.30		751229	760105
48	50	1.0	1.0	0.20	0.24	5.00		5.40		751231	760108
40	37	1.0	1.0	0.25	0.11					760105	760112
40	36	1.0	1.0	0.71	0.19					760108	760114
39	36	1.0	1.0	0.15	0.38					760112	760119
40	37	1.0	1.0	0.29	0.28					760114	760122
36	38	1.0	1.0	0.30	0.30					760119	760126
30	39	1.0	1.0	0.79	0.16					760122	760129

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR DRUID LAKE

PH (LOG,01UNIT)		TOTAL ALKALINITY (MG/L)		HARDNESS AS CACO3 (MG/L)		TOTAL SOLIDS (MG/L)		DISSOLVED SOLIDS (MG/L)		SAMPLE DATE OF I	SAMPLE DATE OF E
I	E	I	E	I	E	I	E	I	E	Y M D	Y M D
7.6	7.6	67	67	75	70	123	117	127	117	750203	750210
7.1	7.5	65	58	75	74	125	120	125	120	750206	750213
7.3	7.2	58	47	65	67	116	125	115	125	750210	750220
7.6	7.8	55	49	71	72	125	115	125	115	750218	750224
7.2	7.6	57	45	61	68	120	91	120	91	750220	750227
7.5	7.5	55	43	73	76	126	100	126	100	750224	750303
7.9	7.3	50	45	73	73	101	113	121	113	750227	750306
7.5	7.6	65	43	76	74	110	95	105	95	750303	750310
7.3	7.5	66	46	76	71	117	82	114	82	750306	750313
7.5	7.8	63	41	76	71	115	55	112	63	750310	750317
7.5	7.6	66	43	69	71	76	65	76	56	750313	750320
7.3	7.5	63	42	75	72	80	51	80	51	750317	750325
7.6	7.6	66	42	72	72	70	59	70	58	750320	750327
7.6	7.5	62	42	72	69	85	66	85	66	750324	750331
7.5	7.5	62	45	72	75	82	62	82	62	750327	750403
7.5	7.7	62	47	68	69	82	137	82	137	750331	750407
7.5	7.5	65	47	73	69	81	137	81	137	750403	750410
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750407	750414
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750410	750417
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750414	750421
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750417	750424
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750421	750428
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750424	750501
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750428	750505
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750501	750507
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750505	750509
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750507	750512
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750509	750514
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750512	750516
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750514	750519
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750516	750521
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750519	750523
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750521	750526
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750523	750528
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750526	750602
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750528	750604
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750602	750606
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750604	750609
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750606	750611
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750609	750613
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750611	750616
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750613	750618
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750616	750620
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	750618	750623
	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	750620	750625
7.1	7.1	70	42	75	72	137	137	137	137	750623	750627
7.1	7.1	69	40	65	74	130	145	124	145	750623	750630

CONTINUED

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR ORLIC LAKE

PH (LAB,STDUNIT)		TOTAL ALKALINITY (LAB,MG/L)		HARDNESS AS CACO3 (LAB,MG/L)		TOTAL SOLIDS (LAB,MG/L)		DISSOLVED SOLIDS (LAB,MG/L)		SAMPLE DATE OF I	SAMPLE DATE OF E
I	E	I	E	I	E	I	E	I	E	Y M D	Y M D
7.1	7.8	52	53	75	61	130	94	129	94	750627	750702
6.7	7.5	50	53	69	62	129	94	129	94	750630	750704
7.9	7.7	52	40	65	63	101	96	101	96	750702	750707
7.6	7.9	55	53	67	60	103	105	103	105	750704	750709
7.1	7.8	50	41	60	56	93	93	93	93	750707	750711
8.0	7.6	47	42	63	63	95	94	95	94	750709	750714
7.9	7.3	50	50	50	65	104	97	103	96	750711	750716
7.6	7.5	38	40	66	54	108	101	108	101	750714	750718
7.3	7.3	33	41	68	48	94	96	94	96	750716	750721
7.2	7.5	37	41	54	62	90	94	87	94	750718	750723
7.0	7.3	51	43	62	62	94	124	94	124	750721	750725
7.5	7.7	51	44	68	51	103	117	103	117	750723	750728
7.3	7.5	55	43	65	66	115	120	115	120	750725	750730
7.4	7.5	55	44	66	67	113	119	113	119	750728	750801
7.5	7.9	58	44	71	65	112	117	112	117	750730	750804
7.5	7.6	55	55	60	65	117	124	117	124	750801	750806
7.9	7.6	55	55	61	59	115	123	115	120	750804	750808
7.1	7.5	52	46	57	57	117	120	117	120	750806	750811
7.5	7.5	55	43	70	72	113	122	113	122	750808	750813
7.5	7.5	56	43	65	72	127	130	127	130	750811	750815
7.5	7.5	50	45	65	77	126	131	126	131	750813	750818
7.5	8.3	51	53	72	71	131	133	131	133	750815	750820
7.5	7.6	55	56	73	77	131	133	131	133	750818	750822
7.5	7.8	58	57	80	75	141	139	141	139	750820	750825
7.3	7.6	55	52	73	80	135	135	135	135	750822	750827
7.7	7.7	50	50	75	75	130	135	130	135	750825	750829
7.3	7.3	50	52	73	74	137	139	137	139	750827	750903
7.6	7.3	50	50	76	100	135	122	135	122	750829	750905
7.1	7.9	56	56	76	88	139	122	139	122	750903	750908
8.1	7.9	55	53	97	72	122	122	122	122	750905	750910
8.7	7.1	55	50	97	88	129	121	129	121	750908	750912
8.1	7.8	56	50	72	85	121	115	122	115	750910	750915
8.5	7.3	52	50	81	85	121	122	121	122	750912	750917
7.5	7.3	50	50	81	85	122	96	122	96	750915	750919
7.3	7.5	56	50	93	88	115	75	115	75	750917	750922
7.1	7.5	56	57	60	75	96	95	95	95	750919	750924
7.1	7.1	51	40	90	85	88	126	86	123	750922	750926
7.3	7.3	58	48	91	89	98	129	94	120	750924	750929
8.8	7.2	55	45	92	84	135	127	135	127	750926	751001
8.5	7.2	35	46	85	81	120	120	120	120	750929	751003
8.5	7.3	37	43	76	80	106	115	106	118	751001	751006
8.1	7.3	35	55	72	78	103	115	103	115	751003	751008
8.5	7.2	41	39	68	77	113	103	113	103	751006	751010
8.3	7.5	50	35	55	77	128	103	127	102	751008	751013
8.2	7.5	32	43	67	75	126	115	105	115	751010	751015
8.5	7.3	53	50	55	70	121	106	122	106	751013	751017
8.2	7.5	55	55	57	72	111	95	111	95	751015	751020

CONTINUED

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR DRUID LAKE

PH LAB,SUNIT		TOTAL ALKALINITY LAB,MG/L		HARDNESS AS CACO3 LAB,MG/L		TOTAL SOLIDS LAB,MG/L		DISSOLVED SOLIDS LAB,MG/L		SAMPLE DATE OF I	SAMPLE DATE OF E
I	E	I	E	I	E	I	E	I	E	Y M D	Y M D
6.7	7.2	65	78	71	67	107	113	102	115	751017	751022
6.1	7.0	37	40	67	72	91	107	91	107	751020	751024
6.1	7.2	39	45	68	76	107	107	107	107	751022	751027
6.0	7.1	39	42	53	72	93	105	99	105	751024	751030
6.9	7.0	40	42	62	71	100	103	100	129	751027	751031
6.9	7.5	42	43	75	72	115	109	111	108	751030	751103
6.9	7.3	42	40	75	61	107	107	103	107	751031	751106
6.9	7.3	40	42	71	80	109	113	108	113	751103	751110
6.9	7.3	40	42	71	74	105	113	107	113	751106	751113
6.7	7.2	45	40	84	71	122	113	122	118	751110	751117
6.5	7.5	41	42	80	79	113	118	113	118	751113	751120
6.7	7.3	42	41	72	76	111	115	111	116	751117	751124
7.1	7.7	50	44	72	71	116	136	114	136	751120	751126
	7.5		41		71		107		107	751124	751201
7.1	7.0	45	43	70	72	135	113	128	110	751126	751204
6.7	7.1	39	43	71	67	107	110	107	110	751201	751208
7.0	7.5	43	44	72	82	103	107	103	107	751204	751211
6.9	7.3	41	42	80	82	110	137	110	107	751208	751215
7.1	7.3	45	39	71	82	107	113	107	113	751211	751218
7.0	7.7	43	41	82	81	107	93	107	98	751215	751222
6.3	7.6	39	44	82	67	113	110	113	110	751218	751226
6.9	7.2	40	42	81	67	107	113	107	114	751222	751229
6.3	7.7	42	41	88	62	107	113	107	110	751225	751231
6.3	7.7	40	35	77	70	110	107	110	107	751229	760105
6.3	7.6	43	42	80	70	106	93	105	97	751231	760108
6.9	7.7	28	36	76	70	107	102	109	102	760105	760112
7.2	7.3	50	34	68	67	91	108	91	138	760108	760115
6.3	7.5	20	35	70	70	105	105	109	106	760112	760119
7.5	7.6	39	34	66	75	108	109	119	108	760115	760122
7.2	7.5	37	39	68	67	104	115	104	114	760119	760126
7.5	7.4	46	36	72	72	106	115	105	116	760122	760129

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR [illegible] LAKE

AMMONIA AS N LD=0.02MG/L		NITRATE AS N LD=0.01MG/L		TOTAL PHOSPHATE AS PO4 LD=0.01MG/L		SOLUBLE ORTHO PHOSPHATE AS PO4 LD=0.01MG/L		COPPER LD=0.001MG/L		SAMPLE DATE OF I	SAMPLE DATE OF F
I	F	I	F	I	F	I	F	I	F	Y M D	Y M D
0.03	0.02	0.5	0.8	0.03	0.01	0.02	0.01	0.008	0.004	750203	750210
0.05	0.03	1.2	0.8	0.02	0.01	0.01	0.01	0.016	0.010	750206	750213
0.02	0.03	1.1	0.7	0.03	0.01	0.03	0.01	0.011	0.002	750210	750218
0.02	0.02	0.5	1.0	0.05	0.03	0.04	0.02	0.005	0.002	750213	750220
0.05	0.02	0.5	1.0	0.05	0.01	0.05	0.01	0.009	0.001	750218	750226
0.03	0.02	0.5	0.9	0.03	0.01	0.02	0.01	0.012	0.005	750220	750227
0.02	0.02	0.7	0.9	0.01	0.03	0.01	0.03	0.021	0.009	750225	750303
0.02	0.02	0.5	0.9	0.06	0.03	0.06	0.03	0.005	0.039	750227	750306
0.02	0.02	1.1	1.1	0.05	0.01	0.04	0.01	0.003	0.005	750303	750310
0.02	0.02	0.8	0.9	0.03	0.01	0.01	0.01	0.009	0.008	750306	750313
0.02	0.02	1.0	1.0	0.02	0.03	0.01	0.01	0.005	0.006	750310	750317
0.02	0.02	0.9	0.9	0.01	0.02	0.01	0.02	0.009	0.010	750313	750320
0.02	0.02	1.0	1.1	0.02	0.03	0.02	0.01	0.004	0.001	750317	750325
0.02	0.02	0.9	1.1	0.07	0.02	0.02	0.02	0.010	0.003	750320	750327
0.07	0.03	1.2	1.1	0.04	0.04	0.01	0.04	0.005	0.002	750325	750331
0.02	0.03	1.2	1.2	0.01	0.03	0.01	0.01	0.003	0.002	750327	750403
0.02	0.07	1.2	1.1	0.04	0.02	0.01	0.02	0.004	0.008	750331	750407
0.02	0.02	1.2	0.9	0.04	0.05	0.04	0.19	0.001	0.001	750403	750410
0.02	0.02	1.1	1.1	0.07	0.08	0.05	0.02	0.011	0.034	750407	750415
0.02	0.02	1.1	0.9	0.05	0.05	0.12	0.03	0.007	0.004	750410	750417
0.02	0.02	0.9	1.1	0.09	0.06	0.08	0.06	0.007	0.031	750415	750421
0.02	0.02	1.0	1.0	0.04	0.04	0.02	0.04	0.019	0.008	750417	750424
0.02	0.02	1.1	0.9	0.08	0.04	0.03	0.04	0.361	0.005	750421	750428
0.02	0.02	1.0	0.9	0.09	0.02	0.04	0.02	0.016	0.049	750424	750501
0.02	0.02	0.9	0.8	0.06	0.08	0.06	0.08	0.016	0.041	750428	750505
0.02	0.02	0.9	0.8	0.01	0.08	0.01	0.08	0.085	0.041	750501	750507
0.02	0.02	1.0	0.8	0.08	0.08	0.01	0.08	0.041	0.029	750505	750509
0.02	0.02	0.9	0.8	0.09	0.08	0.04	0.18	0.034	0.041	750507	750512
0.02	0.02	0.9	0.9	0.10	0.10	0.10	0.10	0.045	0.035	750509	750514
0.02	0.02	0.9	0.7	0.05	0.10	0.05	0.13	0.031	0.026	750512	750516
0.02	0.02	1.0	0.8	0.08	0.08	0.08	0.07	0.022	0.060	750514	750519
0.02	0.02	0.9	0.8	0.10	0.05	0.10	0.03	0.035	0.060	750516	750521
0.02	0.02	0.9	0.9	0.10	0.10	0.10	0.28	0.040	0.040	750519	750523
0.02	0.02	0.9	0.9	0.10	0.09	0.10	0.01	0.056	0.040	750521	750526
0.02	0.02	0.8	0.8	0.10	0.09	0.10	0.02	0.046	0.060	750523	750528
0.02	0.02	0.9	0.9	0.08	0.01	0.01	0.01	0.051	0.060	750526	750602
0.02	0.02	0.8	1.0	0.05	0.01	0.06	0.03	0.040	0.080	750528	750605
0.02	0.02	1.1	1.1	0.11	0.02	0.01	0.11	0.370	0.061	750602	750606
0.02	0.02	1.0	1.2	0.02	0.03	0.02	0.04	0.046	0.029	750604	750609
0.02	0.02	1.1	1.5	0.02	0.05	0.02	0.03	0.025	0.021	750606	750611
0.02	0.02	1.1	0.7	0.01	0.06	0.05	0.16	0.005	0.021	750609	750613
0.02	0.02	1.0	0.8	0.05	0.03	0.31	0.03	0.017	0.026	750611	750616
0.02	0.02	0.3	0.9	0.07	0.03	0.07	0.01	0.006	0.008	750613	750618
0.02	0.02	0.3	0.9	0.06	0.12	0.39	0.26	0.012	0.008	750616	750620
0.03	0.03	0.4	0.8	0.07	0.05	0.07	0.25	0.024	0.008	750618	750623
	0.03		0.9		0.09		0.16		0.015	750620	750625

CONTINUED

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR DRUID LAKE

AMMONIA AS N LD=0.02MG/L		NITRATE AS N LD=0.01MG/L		TOTAL PHOSPHATE AS PO4 LD=0.01MG/L		SOLUBLE ORTHO PHOSPHATE AS PO4 LD=0.01MG/L		COPPER LD=0.001MG/L		SAMPLE DATE OF I	SAMPLE DATE OF E
I	E	I	E	I	E	I	E	I	E	Y M D	Y M D
0.02	0.02	0.9	0.8	0.05	0.02	0.03	0.02	0.008	0.008	790626	790627
0.02	0.02	1.0	0.7	0.02	0.03	0.02	0.39	0.010	0.002	790629	790630
0.02	0.02	1.0	0.9	0.02	0.01	0.02	0.01	0.006	0.010	790627	790703
0.02	0.02	0.9	0.9	0.06	0.01	0.06	0.01	0.002	0.014	790630	790705
0.02	0.02	0.9	0.8	0.01	0.03	0.01	0.03	0.010	0.010	790702	790707
0.02	0.02	0.9	0.9	0.02	0.02	0.02	0.02	0.012	0.022	790705	790709
0.02	0.02	0.8	0.7	0.04	0.01	0.05	0.01	0.022	0.012	790707	790711
0.02	0.02	0.9	0.7	0.02	0.02	0.02	0.02	0.010	0.022	790709	790714
0.02	0.02	0.7	0.7	0.02	0.03	0.02	0.11	0.010	0.017	790711	790716
0.02	0.02	0.7	0.7	0.03	0.05	0.05	0.08	0.010	0.018	790716	790718
0.02	0.02	0.7	0.7	0.03	0.03	0.03	0.01	0.010	0.018	790716	790721
0.02	0.02	0.7	0.7	0.05	0.05	0.05	0.03	0.010	0.010	790718	790723
0.02	0.02	0.7	0.7	0.03	0.02	0.01	0.02	0.010	0.020	790721	790725
0.02	0.02	0.7	0.7	0.01	0.03	0.01	0.03	0.017	0.016	790723	790728
0.02	0.02	0.8	0.8	0.02	0.03	0.02	0.03	0.020	0.020	790725	790730
0.02	0.02	0.7	0.9	0.03	0.03	0.03	0.03	0.012	0.010	790728	790801
0.03	0.02	0.9	0.9	0.03	0.05	0.05	0.09	0.010	0.010	790730	790804
0.02	0.02	0.9	0.8	0.03	0.05	0.03	0.05	0.018	0.014	790801	790806
0.02	0.02	0.9	0.7	0.05	0.05	0.05	0.05	0.015	0.002	790804	790808
0.02	0.02	0.8	0.8	0.38	0.03	0.02	0.03	0.012	0.002	790806	790811
0.02	0.02	0.7	0.7	0.05	0.05	0.05	0.05	0.003	0.007	790808	790813
0.02	0.02	0.8	0.8	0.03	0.03	0.03	0.05	0.003	0.015	790811	790815
0.02	0.02	0.7	0.7	0.05	0.03	0.05	0.38	0.010	0.003	790813	790818
0.02	0.02	0.7	0.7	0.05	0.05	0.06	0.05	0.003	0.003	790815	790820
0.02	0.02	0.7	0.7	0.05	0.05	0.05	0.05	0.004	0.021	790818	790822
0.02	0.02	0.7	0.7	0.01	0.30	0.03	0.16	0.002	0.006	790820	790825
0.02	0.02	0.7	0.8	0.07	0.03	0.07	0.11	0.012	0.004	790822	790827
0.02	0.02	0.7	0.7	0.04	0.09	0.06	0.05	0.003	0.003	790825	790829
0.02	0.02	0.8	0.7	0.03	0.05	0.03	0.05	0.001	0.007	790827	790901
0.02	0.02	0.7	0.6	0.05	0.16	0.09	0.19	0.010	0.002	790829	790904
0.02	0.02	0.7	0.5	0.05	0.05	0.03	0.03	0.013	0.003	790901	790905
0.02	0.02	0.6	0.6	0.05	0.13	0.05	0.01	0.003	0.003	790905	790908
0.02	0.02	0.7	0.5	0.05	0.03	0.03	0.01	0.003	0.012	790905	790910
0.02	0.05	0.6	0.9	0.07	0.01	0.03	0.01	0.003	0.010	790908	790912
0.02	0.02	0.5	0.5	0.03	0.15	0.20	0.05	0.008	0.005	790912	790915
0.05	0.02	0.9	0.5	0.01	0.03	0.01	0.05	0.010	0.020	790912	790917
0.02	0.02	0.5	0.7	0.09	0.05	0.05	0.08	0.003	0.001	790915	790919
0.02	0.02	0.5	0.7	0.09	0.09	0.08	0.06	0.014	0.016	790917	790922
0.02	0.02	0.8	0.8	0.09	0.06	0.09	0.06	0.002	0.018	790919	790924
0.02	0.05	0.5	1.0	0.05	0.05	0.05	0.08	0.016	0.760	790922	790926
0.02	0.02	0.8	1.3	0.07	0.02	0.07	0.13	0.020	0.020	790924	790928
0.15	0.02	0.7	0.9	0.07	0.20	0.00	0.10	0.100	0.040	790926	791001
0.02	0.05	1.3	0.8	0.25	0.01	0.14	0.01	0.010	0.010	790928	791003
0.02	0.03	0.9	0.8	0.15	0.01	0.10	0.01	0.010	0.020	791001	791005
0.05	0.03	0.9	0.9	0.01	0.01	0.01	0.01	0.020	0.020	791003	791008
0.05	0.02	0.8	0.8	0.01	0.02	0.01	0.02	0.020	0.020	791005	791010

CONTINUED

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR ORLID LAKE

AMMONIA AS N LD=0.02MG/L		NITRATE AS N LD=0.01MG/L		TOTAL ORTHO-PHATE AS PO4 LD=0.01MG/L		SOLUBLE ORTHO PHOSPHATE AS PO4 LD=0.01MG/L		COPPER LD=0.001MG/L		SAMPLE DATE OF 1	SAMPLE DATE OF 2
I	B	I	B	I	B	I	B	I	B	Y M D	Y M D
0.03	0.02	1.0	0.9	0.01	0.07	0.01	0.02	0.020	0.010	751008	751013
0.02	0.02	0.9	1.0	0.02	0.02	0.02	0.01	0.010	0.020	751013	751015
0.02	0.02	0.9	1.0	0.04	0.02	0.02	0.01	0.010	0.020	751013	751017
0.02	0.05	1.1	1.0	0.01	0.01	0.01	0.01	0.020	0.020	751015	751020
0.02	0.05	1.0	0.9	0.01	0.03	0.02	0.02	0.010	0.030	751017	751022
0.03	0.10	1.3	1.0	0.01	0.03	0.01	0.02	0.010	0.020	751020	751024
0.05	0.02	1.2	1.1	0.02	0.02	0.02	0.02	0.010	0.020	751022	751027
0.05	0.02	1.4	0.8	0.01	0.05	0.02	0.05	0.030	0.202	751024	751030
0.02	0.02	1.1	0.6	0.02	0.10	0.02	0.10	0.040	0.308	751027	751031
0.02	0.02	0.9	0.5	0.05	0.02	0.03	0.02	0.003	0.310	751030	751103
0.02	0.02	0.3	0.7	0.12	0.01	0.12	0.01	0.003	0.005	751031	751105
0.02	0.02	1.0	1.5	0.02	0.05	0.02	0.02	0.003	0.005	751103	751110
0.02	0.02	0.9	1.3	0.01	0.02	0.01	0.02	0.003	0.002	751106	751113
0.02	0.03	1.0	1.4	0.04	0.05	0.04	0.05	0.007	0.005	751110	751117
0.03	0.02	1.4	1.4	0.03	0.08	0.03	0.03	0.005	0.005	751113	751120
0.02	0.02	1.4	1.5	0.01	0.79	0.01	0.34	0.001	0.003	751117	751124
0.02	0.02	1.4	1.5	0.02	0.02	0.02	0.02	0.007	0.106	751120	751126
	0.02		1.6		0.01		0.01		0.070	751124	751201
0.02	0.02	1.5	1.3	0.02	0.05	0.03	0.73	0.010	0.060	751125	751205
0.02	0.02	1.6	1.7	0.01	0.01	0.01	0.01	0.070	0.387	751201	751203
0.02	0.02	1.7	1.6	0.01	0.01	0.01	0.01	0.050		751205	751211
0.02	0.05	1.6	1.3	0.02	0.01	0.02	0.71	0.070		751208	751215
0.02	0.02	0.9	1.5	0.01	0.01	0.01	0.01			751211	751219
0.05	0.02	1.1	1.5	0.01	0.01	0.01	0.71			751215	751222
0.02	0.02	1.6	1.6	0.01	0.05	0.01	0.01		0.310	751219	751226
0.02	0.02	1.5	1.5	0.01	0.06	0.01	0.02		0.310	751222	751229
0.02	0.03	1.5	1.8	0.04	0.06	0.05	0.05	0.010	0.010	751226	751231
0.02	0.02	1.9	1.2	0.10	0.01	0.01	0.01	0.050	0.010	751229	760105
0.03	0.02	1.7	1.2	0.06	0.02	0.03	0.01	0.010	0.010	751231	760109
0.02	0.02	1.6	0.5	0.31	0.02	0.01	0.01	0.010	0.020	760105	760112
0.02	0.02	1.5	1.2	0.08	0.01	0.06	0.01	0.010	0.010	760109	760116
0.03	0.03	1.3	1.3	0.02	0.01	0.31	0.31	0.030	0.010	760112	760119
0.02	0.02	1.3	1.5	0.01	0.02	0.02	0.01	0.010	0.010	760116	760122
0.02	0.02	1.3	1.7	0.02	0.32	0.51	0.32	0.120	0.013	760119	760126
0.02	0.03	1.4	1.2	0.03	0.02	0.31	0.02	0.010	0.010	760122	760129

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR [illegible] LAKE

ZINC		SUSPENDED SOLIDS		PHYTO-PLANKTON			SAMPLE DATE OF 1	SAMPLE DATE OF SEC
LO=0.001MG/L		LO=0.1MG/L		LT40 ORGANISMS/ML				
1	2	1	2	1	2	3	Y M D	Y M D
0.015	0.006	0.1	0.1	1	23		750203	750210
0.010	0.008	1.0	0.1	12	5	6	750206	750213
0.008	0.008	0.5	0.1	16	3	2	750211	750218
0.008	0.013	0.1	0.1	4	0	1	750213	750220
0.009	0.014	0.1	0.1	9	1	2	750218	750225
0.013	0.011	0.1	0.1	1	1	0	750220	750227
0.010	0.017	0.1	0.5	25	10	0	750225	750303
0.011	0.015	0.6	0.1	1	1	0	750227	750306
0.011	0.015	1.5	0.6	160	7	51	750303	750310
0.011	0.008	0.9	0.1	31	6	15	750306	750313
0.015	0.003	1.9	0.1	133	5	26	750310	750317
0.015	0.003	0.1	0.1	4	22	9	750313	750320
0.013	0.004	0.1	0.1	12	0	1	750317	750325
0.013	0.006	0.1	0.1	16	1	6	750320	750327
0.010	0.020	0.1	0.1	1	2	1	750325	750331
0.020	0.020	0.1	0.1	1	12	0	750327	750403
0.020	0.005	0.1	0.6	0	12	11	750331	750407
0.010	0.011	0.3	0.1	1	3	1	750403	750410
0.00[illegible]	0.012	0.1	0.2	1	8	1	750407	750414
0.005	0.005	0.2	0.3	1	2	1	750410	750417
0.010	0.011	0.1	0.1	0	1	0	750414	750421
0.005	0.010	0.2	0.1	1	16	1	750417	750425
0.010	0.010	1.5	0.1	1	5	0	750421	750428
0.010	0.008	0.5	0.1	1	5	0	750424	750501
0.010	0.005	0.1	0.1	1	7	0	750428	750505
0.010	0.005	0.1	0.1	0	0	0	750501	750507
0.008	0.008	0.1	0.1	1	1	0	750505	750509
0.009	0.005	0.5	0.1	1	1	0	750507	750512
0.009	0.004	0.1	0.1	0	1	1	750509	750514
0.008	0.008	0.1	0.1	0	1	0	750512	750516
0.004	0.010	0.1	0.1	1	1	14	750514	750519
0.009	0.017	0.1	0.1	0	1	0	750516	750521
0.020	0.017	0.1	0.1	1	0	1	750519	750523
0.017	0.020	0.1	0.1	0	1	0	750521	750526
0.020	0.020	0.1	0.1	0	0	0	750523	750528
0.020	0.020	0.1	0.1	0	0	0	750526	750602
0.020	0.020	0.1	0.1	0	0	0	750528	750604
0.020	0.020	0.1	0.1	0	0	0	750602	750606
0.020	0.023	0.1	0.1	0	0	0	750604	750609
0.015	0.015	0.1	0.1	1	0	0	750606	750611
0.020	0.020	0.2	0.1	0	0	0	750609	750613
0.015	0.015	0.2	0.1	0	0	0	750611	750616
0.010	0.015	0.2	0.1	0	1	1	750613	750618
0.010	0.011	0.2	0.3	0	12	0	750616	750620
0.008	0.009	0.2	0.2	0	5	0	750618	750623
	0.017		0.2				750620	750625
0.007	0.008	0.1	0.2	0	0	0	750623	750627

CONTINUED

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR TRUIC LAKE

LEAD, (MG/L)		SUSPENDED SOLIDS LOAD, (MG/L)		LOAD	BENTHIC PLANKTON ORGANISMS/ML		SAMPLE DATE OF I	SAMPLE DATE OF REC
I	O	I	O	I	O	C	Y M D	Y M D
0.011	0.008	0.8	0.1	15	8	15	750621	750630
0.008	0.005	1.0	0.2	7	2	2	750627	750702
0.017	0.005	0.2	0.2	0	0	0	750630	750705
0.005	0.005	0.1	1.7	6	6	3	750702	750707
0.005	0.005	0.2	0.1	0	8	21	750705	750709
0.003	0.005	0.2	0.8	4	1	1	750707	750711
0.005	0.015	0.1	0.1	2	0	1	750709	750714
0.005	0.005	1.2	0.1	5	0	1	750711	750716
0.005	0.005	0.1	0.1	0	0	0	750714	750718
0.005	0.010	0.1	0.2	2	0	0	750716	750721
0.005	0.020	0.7	0.1	0	0	2	750718	750723
0.010	0.020	0.4	0.1	1	1	1	750721	750725
0.010	0.010	0.1	0.1	1	0	2	750723	750728
0.005	0.010	0.2	0.1	1	0	0	750725	750730
0.005	0.010	0.1	0.2	1	0	0	750728	750801
0.010	0.005	0.1	0.1	0	0	0	750730	750804
0.005	0.010	0.2	0.1	2	1	0	750801	750806
0.010	0.003	0.1	0.1	2	0	0	750804	750808
0.015	0.004	0.2	0.1	0	0	0	750806	750811
0.005	0.005	1.5	0.1	0	2	0	750808	750813
0.003	0.005	0.2	0.1	0	0	0	750811	750815
0.001	0.005	1.2	0.1	0	0	0	750813	750818
0.005	0.020	0.1	0.1	4	0	0	750815	750820
0.003	0.008	0.1	0.1	0	0	0	750818	750822
0.003	0.003	0.1	0.1	0	1	0	750820	750825
0.005	0.005	0.1	0.1	0	0	0	750822	750827
0.010	0.003	0.2	0.1	1	0	0	750825	750829
0.003	0.003	0.1	0.1	0	0	0	750827	750901
0.003	0.003	0.1	0.1	0	0	0	750829	750903
0.005	0.003	0.1	0.1	0	0	0	750901	750905
0.003	0.005	0.1	0.2	0	0	0	750903	750908
0.003	0.003	0.2	0.2	0	0	0	750905	750910
0.001	0.020	0.2	0.2	0	0	0	750908	750912
0.003	0.005	0.1	0.1	0	0	1	750910	750915
0.010	0.006	0.2	0.1	32	0	0	750912	750917
0.007		0.2	0.2	0	0	0	750915	750919
0.001	0.005	0.2	0.2	1	1	1	750917	750922
0.001	0.010	0.1	0.1	0	0	0	750919	750924
0.003	0.010	0.1	0.1	1	0	0	750922	750926
0.010	0.010	0.4	0.2	1	0	0	750924	750929
0.010	0.010	0.2	0.2	0	0	0	750926	751001
0.010	0.020	0.3	0.5	0	0	0	750929	751003
0.010	0.010	0.2	0.5	0	0	0	751001	751006
0.005	0.005	0.1	0.1	1	0	0	751003	751008
	0.020	0.1	0.1	0	0	15	751006	751010
0.007	0.003	0.5	0.5	0	0	0	751008	751013
0.010	0.004	0.4	0.6	4	13	0	751010	751015

CONTINUED

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA PER CRUIC LAKE

LEAD LOAD,CC(MG/L		SUSPENDED SOLIDS LOAD,(MG/L		PHYTO- PLANKTON LOAD CELLS(1000S)/ML			SAMPLE DATE OF T	SAMPLE DATE OF SEC
T	B	T	B	T	B	C	Y M D	Y M D
0.005	0.026	0.5	1.1	6	12	1	751013	751017
0.006	0.032	0.7	0.5	7	9	0	751015	751020
0.017	0.017	0.5	0.5	6	5	1	751017	751022
0.025	0.017	0.3	0.5	1	3	1	751020	751024
0.012	0.017	0.5	0.7	1	5	2	751022	751027
0.035	0.007	0.2	0.2	4	2	3	751024	751030
0.012	0.007	0.2	0.2	2	1		751027	751031
0.007	0.005	0.1	0.1	0	1		751030	751103
0.007	0.005	0.1	0.1	1	1		751031	751106
0.008	0.008	0.1	0.1	3	26		751103	751110
0.005	0.001	0.1	0.1	1	4		751106	751113
0.007	0.005	0.1	0.1	2	4	10	751110	751117
0.003	0.003	0.1	0.1	1	56		751113	751120
0.007	0.005	0.1	0.1	0	36	134	751117	751124
0.065	0.010	0.1	0.1	0	156		751120	751126
	0.020		0.1	0	25	21	751124	751201
0.014	0.020	0.1	0.1	0	17	36	751126	751204
0.013	0.015	0.1	0.1	0	20	10	751201	751208
0.020	0.005	0.1	0.1	1	21		751204	751211
0.015	0.003	0.1	0.1	6	17	7	751208	751215
0.005	0.005	0.1	0.1	1	0	10	751211	751218
0.005	0.005	0.1	0.1	1	4	5	751215	751222
0.005	0.011	0.1	0.2	0	12	5	751218	751226
0.005	0.013	0.1	0.2	1	4	5	751222	751229
0.025	0.020	0.2	0.2	1	15	11	751226	751231
0.007		0.2	0.5	8	0	1	751229	760105
0.014	0.025	0.2	0.6	0		14	751231	760108
	0.020	0.5	0.2	1	5	11	760105	760112
0.013	0.019	0.5	0.5		3	8	760108	760116
0.013	0.025	0.4	0.2	6	2		760112	760119
0.013	0.025	0.2	0.3		0	1	760116	760122
0.023	0.013	0.2	0.5		0	1	760119	760126
0.025	0.025	0.1	0.1		1	4	760122	760129

TABLE [illegible]

WATER QUALITY SAMPLING DATA FOR [illegible] RESERVOIR NO. 1

[illegible]

TOTAL COLIFORM LEVEL [illegible]	TOTAL STANDARD PLATE COUNT LEVEL [illegible]	[illegible] LEVEL ORGANISMS/ML	SAMPLE DATE [illegible]	SAMPLE DATE [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CONTINUED

TABLE [illegible]

[illegible]

CONTINUED

TABLE 8-1

[illegible] QUALITY SAMPLING DATA FOR [illegible] NO. 1

TOTAL COLIFORMS COLONIES/100ML			TOTAL STANDARD PLATE COUNT COLONIES/ML			PHYTO-PLANKTON ORGANISMS/ML			SAMPLE DATE OF 1	SAMPLE DATE OF [illegible]
1	2	3	1	2	3	1	2	3	Y M D	Y M D
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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TABLE [illegible] (CONTINUED)

WATER QUALITY SAMPLING DATA [illegible]

TEMPERATURE CENTIGRADE			APPARENT COLOR COLOR UNIT			TURBIDITY [illegible]			SAMPLE DATE [illegible]	SAMPLE DATE [illegible]
1	2	3	1	2	3	1	2	3	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

TEMPERATURE DEGREES,F			APPARENT COLOR COLOR UNIT			TURBIDITY (FTU,JTU)			SAMPLE DATE OF T	SAMPLE DATE OF ANAL
T	M	B	T	M	B	T	M	B	Y M D	Y M D
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

TEMPERATURE (DEGREES F)			APPARENT COLOR (PT-CO UNIT)			TURBIDITY (JTU)			SAMPLE DATE OF A	SAMPLE DATE OF B&C
A	B	C	A	B	C	A	B	C	Y M D	Y M D
43	42	40	1	1	1	0.72	0.40	1.21	751118	751123
43	45	44	1	1	1	0.35	0.53	0.69	751120	751125
43	46	46	1	1	1	0.12	0.45	0.43	751125	751202
41	42	40	1	1	1	0.60	7.12	0.51	751202	751204
43	43	44	1	1	1	0.51	0.25	0.37	751204	751209
41	38	38	1	1	1	0.70	0.38	0.51	751209	751211
40	40	40	1	1	1	0.17	0.78	0.75	751211	751216
40	37	37	1	1	1	1.20	0.43	0.77	751216	751218
41	39	39	1	1	1	0.32	0.28	0.34	751218	751223
37	37	37	1	1	1	0.28	0.52	0.38	751223	751230
36	38	37	1	1	1	0.56	0.30	0.63	751230	760106
39	35	36	1	1	1	0.68	0.56	0.72	760106	760113
36	36	36	1	1	1	0.36	0.20	0.36	760113	760115
39	36	36	1	1	1	0.35	0.36	0.63	760115	760120
37	38	40	1	1	1	0.51	0.30	0.60	760120	760127
33	36	36	1	1	1	0.91	0.22	0.19	760127	760129

TABLE D-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR RICHLAND RESERVOIR NO. 1

FREE CHLORINE [illegible]			TOTAL CHLORINE [illegible]			PH [illegible]			SAMPLE DATE OF I	SAMPLE DATE OF END
I	B	C	I	B	C	I	B	C	Y M D	Y M D
0.18	0.13	0.16	0.13	0.16	0.10	8.05	8.60	8.70	750203	750206
0.19	0.20	0.20	0.19	0.27	0.29	8.80	8.59	8.30	750206	750210
0.30	0.05	0.10	0.50	0.06	0.10	8.90	8.08	8.00	750210	750213
0.70	0.10	0.08	0.75	0.13	0.13	8.75	8.70	8.50	750213	750218
0.10	0.38	0.08	0.18	0.13	0.13	8.90	8.60	8.60	750218	750220
0.20	0.08	0.03	0.28	0.15	0.13	9.00	8.75	8.70	750220	750225
0.60	0.03	0.01	0.70	0.12	0.10	8.90	9.20	8.63	750225	750227
0.55	0.11	0.10	0.85	0.52	0.50	8.20	8.21	8.18	750227	750303
0.60	0.10	0.10	1.37	0.35	0.31	8.90	8.80	8.23	750303	750306
0.18	0.37	0.10	0.84	0.42	0.12	8.93	8.18	8.13	750306	750310
0.10	0.10	0.05	0.40	0.27	0.25	8.15	7.90	7.90	750310	750313
0.10	0.10	0.05	0.35	0.23	0.22	7.90	7.88	7.90	750313	750317
0.10	0.10	0.08	0.31	0.26	0.15	7.80	7.72	7.73	750317	750320
0.28	0.07	0.08	0.28	0.28	0.16	7.70	7.90	7.05	750320	750324
0.50	0.07	0.08	0.93	0.39	0.31	7.90	7.80	7.73	750324	750327
0.55	0.05	0.02	1.05	0.11	0.12	7.83	7.84	7.80	750327	750331
0.72	0.09	0.04	0.95	0.14	0.11	7.50	7.65	7.75	750331	750403
0.80	0.05	0.05	1.00	0.05	0.05	7.90	7.74	7.70	750403	750407
0.08	0.17	0.05	0.08	0.20	0.39	7.70	7.90	7.80	750407	750410
0.75	0.01	0.01	0.85	0.31	0.01	8.00	7.80	7.83	750410	750414
0.45	0.01	0.01	1.60	0.05	0.09	7.83	7.63	7.80	750414	750417
0.30	0.01	0.01	0.48	0.01	0.01	7.80	7.94	7.90	750417	750421
0.15	0.04	0.03	0.40	0.07	0.05	8.10	8.03	8.00	750421	750424
0.13	0.13	0.02	0.30	0.22	0.23	7.90	7.90	7.90	750424	750428
0.22	0.03	0.02	0.46	0.06	0.34	8.00	7.80	7.80	750428	750501
0.37	0.07	0.05	0.45	0.46	0.35	7.70	8.04	7.90	750501	750505
0.40	0.02	0.01	0.86	0.37	0.34	8.00	8.00	7.90	750505	750508
0.12	0.05	0.03	0.83	0.38	0.75	8.00	7.90	7.90	750508	750512
0.09	0.23	0.03	0.80	0.60	0.54	7.93	7.75	7.70	750512	750515
0.20	0.05	0.03	0.89	0.74	0.60	7.70	7.63	7.80	750515	750519
0.10	0.07	0.06	1.16	0.74	0.41	7.73	7.74	7.83	750519	750522
0.20	0.05	0.42	1.00	0.98	0.47	7.80	7.93	7.80	750522	750527
0.12	0.37	0.03	0.75	0.52	0.35	7.50	7.90	7.85	750527	750529
0.18	0.03	0.01	0.72	0.06	0.32	7.90	7.93	7.85	750529	750602
0.14	0.02	0.02	0.27	0.05	0.02	7.83	7.93	7.83	750602	750604
0.02	0.02	0.02	0.12	0.07	0.03	7.90	8.00	7.95	750604	750606
0.18	0.08	0.02	0.13	0.02	0.32	8.00	8.13	8.10	750606	750609
0.04	0.02	0.02	0.25	0.07	0.27	8.13	7.72	7.83	750609	750611
0.06	0.10	0.01	0.13	0.29	0.31	7.50	8.03	7.93	750611	750616
0.12	0.05	0.30	0.58	0.20	0.83	7.90	7.54	7.75	750616	750618
0.90	0.39	0.03	0.65	0.39	0.44	8.00	7.95	7.20	750618	750620
0.20	0.01	0.02	0.83	0.17	0.31	8.00	7.91	7.35	750620	750623
0.97	0.04	0.08	0.73	0.13	0.14	8.13	8.00	7.45	750623	750625
0.50	0.01	0.01	1.30	0.01	0.01	8.10	7.83	7.43	750625	750630
0.01	0.31	0.01	0.01	0.07	0.04	8.50	8.03	7.90	750630	750702
0.19	0.37	0.02	0.20	0.54	0.25	8.10	7.98	7.90	750702	750707
0.40	0.03	0.03	1.92	0.21	0.47	7.80	8.00	7.05	750702	750707

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TABLE D-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

FREE CHLORINE LOG0.01MG/L I	B	C	TOTAL CHLORINE LOG0.01MG/L I	B	C	PH LOG0.01UNIT I	B	C	SAMPLE DATE OF I Y M D	SAMPLE DATE OF REG Y M D
0.12	0.25	0.10	0.67	0.61	0.80	8.02	7.90	7.32	750707	750709
1.10	0.37	0.87	2.26	0.71	0.73	7.90	7.94	7.80	750709	750711
0.58	0.1	0.10	0.94	0.53	0.94	8.13	8.00	7.65	750711	750715
0.15	0.05	0.33	0.58	0.87	0.53	8.00	7.63	7.75	750714	750716
0.96	0.07	0.17	0.92	0.15	0.11	7.90	7.74	7.80	750716	750718
0.21	0.19	0.19	0.01	0.28	0.31	8.30	8.15	7.80	750718	750722
1.10	0.18	0.14	2.00	0.76	0.91	8.50	8.00	7.30	750721	750723
1.90	0.33	0.36	4.00	0.79	0.78	8.20	8.00	7.65	750723	750725
1.50	0.12	0.11	0.70	0.84	0.96	8.00	8.17	8.10	750725	750728
0.60	0.12	0.10	1.30	0.61	0.19	8.31	8.03	8.50	750728	750730
0.90	0.11	0.10	1.90	0.14	0.13	8.50	8.50	8.20	750730	750801
0.90	0.16	0.06	0.86	0.22	0.13	8.10	8.00	7.98	750801	750804
0.19	0.04	0.06	0.25	0.19	0.17	8.30	8.25	8.13	750804	750806
0.24	0.19	0.21	0.26	0.31	0.33	8.31	8.17	8.05	750806	750808
0.08	0.35	0.31	0.23	0.58	0.53	8.20	8.25	8.00	750808	750811
0.90	0.70	0.83	1.15	0.86	0.88	8.10	8.00	8.00	750811	750813
1.08	0.42	0.36	1.20	0.69	0.70	8.10	8.08	8.05	750813	750815
0.81	0.29	0.26	0.91	0.57	0.92	8.00	8.00	7.90	750815	750818
0.38	0.21	0.19	0.84	0.61	0.63	8.00	8.17	8.00	750818	750820
0.60	0.22	0.20	1.00	0.60	0.55	8.10	8.00	7.95	750820	750822
0.57	0.33	0.03	0.58	0.11	0.13	7.90	7.88	7.85	750822	750825
0.12	0.13	0.04	0.28	0.12	0.19	7.80	7.80	7.80	750825	750827
0.27	0.04	0.02	0.35	0.10	0.10	7.80	7.90	7.90	750827	750829
0.18	0.10	0.10	0.24	0.50	0.51	7.63	7.53	7.63	750829	750903
0.10	0.14	0.10	0.26	0.01	0.74	8.00	7.53	7.30	750903	750905
0.40	0.12	0.14	0.55	0.50	0.63	8.00	7.96	7.90	750905	750908
0.15	0.10	0.10	0.37	0.75	0.86	8.03	7.90	7.40	750908	750910
0.10	0.10	0.10	0.72	0.56	0.51	8.03	8.03	7.65	750910	750912
0.10	0.02	0.02	0.66	0.06	0.07	8.00	8.10	7.53	750912	750915
0.03	0.10	1.05	0.14	0.72	4.15	8.20	8.00	7.35	750915	750917
0.18	0.05	0.05	1.50	0.82	0.61	8.00	7.90	7.80	750917	750919
0.38	0.35	0.04	1.17	0.10	0.17	8.02	7.83	7.73	750919	750922
0.50	0.08	0.04	0.67	0.63	0.47	7.90	8.23	7.90	750922	750924
0.90	0.12	0.10	1.00	0.68	0.64	8.70	8.23	8.20	750924	750926
0.50	0.13	0.10	1.84	0.75	0.65	8.80	8.02	8.00	750926	750929
0.55	0.20	0.58	1.35	0.28	0.37	7.60	7.86	7.65	750929	751001
0.78	0.11	0.07	1.00	0.92	0.71	7.63	7.73	7.70	751001	751003
0.98	0.13	0.06	1.97	0.19	0.16	7.70	7.30	7.40	751003	751007
0.90	0.03	0.02	1.00	0.09	0.05	7.60	7.60	7.70	751007	751009
0.35	0.02	0.02	0.52	0.05	0.28	7.93	8.00	7.90	751009	751014
0.03	0.03	0.02	0.05	0.11	0.06	8.10	7.88	7.90	751014	751016
0.56	0.06	0.00	0.68	0.10	0.35	7.83	7.93	7.83	751016	751021
0.60	0.12	0.06	0.72	0.16	0.07	7.90	7.80	7.80	751021	751023
0.70	0.08	0.04	0.78	0.13	0.10	7.90	7.83	7.90	751023	751028
0.90	0.06	0.07	0.73	0.25	0.19	8.00	7.80	7.30	751028	751030
0.08	0.20	0.12	0.21	0.50	0.88	7.90	7.90	7.85	751030	751104
0.92	0.39	0.07	1.50	0.79	1.65	7.40	8.00	7.5	751104	751113
0.60	0.11	0.11	1.46	1.30	0.50	8.10	8.00	7.90	751113	751118

CONTINUED

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

FREE CHLORINE LD=0.01MG/L			TOTAL CHLORINE LD=0.01MG/L			PH LD=0.01UNIT			SAMPLE DATE OF I	SAMPLE DATE OF E&C
I	E	C	I	E	C	I	E	C	Y M D	Y M D
0.90	0.10	0.60	0.90	1.02	1.91	8.01	7.90	7.94	751118	751120
0.18	0.08	0.07	1.12	0.60	0.15	7.90	8.25	8.00	751123	751125
0.50	0.13	0.11	2.10	0.17	0.13	8.30	7.85	7.75	751129	751202
0.49	0.29	0.12	1.69	0.39	0.18	7.90	7.80	7.80	751202	751205
0.17	0.60	0.18	1.06	0.70	0.21	7.80	7.93	7.90	751206	751209
0.32	0.21	0.21	0.92	0.31	0.30	8.00	7.80	7.80	751209	751211
1.91	0.29	0.19	1.30	0.44	0.28	7.30	7.90	7.50	751211	751216
1.12	0.12	0.08	1.20	0.64	0.7	7.93	8.00	8.00	751216	751218
1.20	0.29	0.22	1.06	0.35	0.27	8.10	7.60	7.83	751218	751220
1.22	0.81	0.12	1.28	0.35	0.28	7.80	7.76	7.70	751223	751230
0.68	0.10	0.19	1.25	0.17	0.32	7.90	8.37	7.80	751230	760108
0.98	0.33	0.33	1.18	0.37	0.33	7.90	8.00	8.00	760106	760112
0.62	0.03	0.06	0.70	0.06	0.39	8.23	8.58	7.95	760113	760116
0.15	0.07	0.13	0.20	0.08	0.13	8.13	7.99	8.15	760119	760120
0.93	0.19	0.13	0.96	0.26	0.15	8.20	8.20	8.13	760123	760127
0.98	0.18	0.17	0.89	0.19	0.19	8.20	8.38	8.37	760127	760129

TABLE 9-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

TOTAL ALKALINITY LEV (MG/L)			HARDNESS AS CACO3 LEV (MG/L)			TOTAL SOLIDS LEV (MG/L)			SAMPLE DATE OF I	SAMPLE DATE OF [illegible]
I	[illegible]	[illegible]	I	[illegible]	[illegible]	I	[illegible]	[illegible]	Y M D	Y M D
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CONTINUED

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

TOTAL ALKALINITY (MG/L)			HARDNESS AS CACO3 (MG/L)			TOTAL SOLIDS (MG/L)			SAMPLE DATE OF T	SAMPLE DATE OF B&C
T	B	C	T	B	C	T	B	C	Y M D	Y M D
28	26	29	125	124	121	259	262	263	750707	750709
28	25	26	157	131	131	321	273	275	750709	750711
27	24	27	142	135	138	285	265	255	750711	750713
27	26	28	140	138	135	289	273	272	750713	750716
29	27	27	150	152	151	281	258	251	750714	750718
32	25	28	158	150	150	316	324	324	750718	750721
35	25	25	158	156	158	325	331	324	750721	750723
31	28	29	166	153	161	290	318	320	750723	750725
34	33	43	150	157	156	318	316	317	750725	750728
42	35	35	162	155	158	302	325	335	750728	750730
40	35	33	160	155	160	322	308	318	750730	750801
35	35	37	160	160	157	313	306	318	750801	750804
40	38	39	164	165	156	319	312	327	750804	750806
38	37	36	170	166	166	351	327	331	750806	750808
38	38	38	170	167	166	351	323	320	750808	750811
40	37	38	158	160	163	285	327	317	750811	750813
40	39	40	156	162	162	316	316	308	750813	750815
40	42	42	162	165	165	317	324	325	750815	750818
38	41	38	160	163	167	326	329	327	750818	750820
37	33	34	163	163	162	311	316	328	750820	750822
30	32	31	162	151	155	310	317	323	750822	750825
33	32	31	150	150	155	316	319	313	750825	750827
31	31	31	150	152	151	300	310	312	750827	750829
31	35	35	150	151	150	301	281	281	750829	750902
41	27	[illegible]	128	127	131	287	236	233	750903	750905
37	37	36	124	128	123	246	225	245	750905	750908
31	34	34	112	120	121	221	229	232	750908	750910
33	33	35	112	115	115	227	218	218	750910	750912
35	34	33	118	123	123	224	215	220	750912	750915
35	34	35	132	120	125	218	232	235	750915	750917
35	34	35	124	117	120	228	228	[illegible]	750917	750919
33	33	33	116	117	117	227	208	209	750919	750922
33	33	32	108	111	112	155	210	212	750922	750924
30	34	33	106	110	105	154	200	201	750924	750926
37	34	34	108	112	111	201	201	203	750926	750929
30	31	30	110	112	111	251	209	211	750929	751001
27	28	28	104	108	105	156	200	213	751001	751003
28	28	21	105	115	108	170	180	177	751003	751007
30	29	28	113	108	105	183	185	180	751007	751009
30	32	30	110	112	112	199	199	201	751009	751015
33	30	30	112	112	114	203	216	221	751015	751016
28	31	31	112	110	110	217	190	130	751016	751021
31	30	30	106	104	106	178	180	181	751021	751023
29	28	30	96	95	95	160	186	190	751023	751028
25	30	30	92	93	94	175	183	184	751028	751030
32	32	30	98	97	97	174	171	171	751030	751106
28	25	24	102	104	103	165	158	200	751106	751112
38	33	35	106	101	107	206	174	173	751112	751114

CONTINUED

TABLE 8-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

TOTAL ALKALINITY (MG/L)			HARDNESS AS CACO3 (MG/L)			TOTAL SOLIDS (MG/L)			SAMPLE DATE OF I	SAMPLE DATE OF T&C
I	B	C	I	B	C	I	B	C	Y M D	Y M D
35	35	33	104	102	104	168	172	173	751118	751120
32	32	32	102	101	103	167	190	191	751120	751125
36	32	31	110	112	110	155	171	175	751125	751202
30	31	31	115	105	110	176	160	177	751202	751205
34	31	31	112	102	102	142	196	197	751205	751209
31	35	33	100	95	95	161	192	194	751209	751211
35	32	32	96	97	97	176	159	170	751211	751216
32	32	32	86	93	92	182	161	161	751216	751218
30	29	29	97	85	90	145	136	129	751218	751223
28	30	30	88	86	86	122	157	150	751223	751230
33	30	29	92	85	90	161	76	130	751230	760106
26	27	27	90	96	96	133	172	170	760106	760113
25	30	28	98	95	97	166	92	170	760113	760115
28	17	31	102	57	101	154	57	169	760115	760120
32	30	30	98	101	101	172	104	149	760120	760127
33	31	32	98	112	112	202	198	196	760127	760129

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

DISSOLVED SOLIDS LOD=1MG/L I	DISSOLVED SOLIDS LOD=1MG/L B	DISSOLVED SOLIDS LOD=1MG/L E	AMMONIA AS N LOD=0.02MG/L I	AMMONIA AS N LOD=0.02MG/L B	AMMONIA AS N LOD=0.02MG/L E	NITRATE AS N LOD=0.01MG/L I	NITRATE AS N LOD=0.01MG/L B	NITRATE AS N LOD=0.01MG/L E	SAMPLE DATE OF I Y M D	SAMPLE DATE OF B&E Y M D
163	159	156	0.02	0.02	0.02	0.80	0.71	0.80	750204	750206
156	158	155	0.02	0.02	0.02	0.60	0.60	0.70	750206	750210
157	89	166	0.06	0.01	0.02	0.60	0.35	0.60	750210	750213
176	181	178	0.02	0.02	0.02	0.60	0.86	0.90	750213	750218
171	180	180	0.02	0.02	0.02	0.90	0.60	0.60	750218	750220
204	183	187	0.02	0.02	0.02	0.60	0.80	0.80	750220	750225
185	179	178	0.02	0.02	0.02	0.80	0.70	0.70	750225	750227
156	185	183	0.02	0.02	0.02	0.60	0.66	0.70	750227	750304
159	183	183	0.02	0.02	0.02	0.50	0.70	0.70	750303	750306
178	177	178	0.02	0.02	0.03	0.70	0.60	0.75	750306	750310
185	168	175	0.02	0.02	0.02	0.60	0.60	0.60	750310	750313
170	180	179	0.02	0.02	0.02	0.60	0.60	0.60	750313	750317
180	178	179	0.02	0.05	0.05	0.60	0.65	0.70	750317	750320
180	173	173	0.02	0.03	0.05	0.70	0.60	0.65	750320	750324
187	186	184	0.06	0.04	0.05	0.50	0.50	0.55	750325	750327
166			0.02	0.02	0.02	0.60	0.70	0.70	750327	750331
	160	167	0.02	0.02	0.02	0.70	1.00	1.00	750331	750404
168	164	169	0.02	0.02	0.02	1.00	0.90	0.90	750404	750407
167	158	153	0.02	0.02	0.02	0.90	0.70	0.70	750407	750410
159	157	151	0.02	0.02	0.02	0.70	0.70	0.85	750410	750414
150	156	154	0.02	0.02	0.02	0.90	0.80	0.80	750414	750417
160	166	168	0.02	0.02	0.02	0.60	1.00	1.05	750417	750421
184	171	175	0.02	0.02	0.02	1.00	0.90	0.90	750421	750424
180	173	176	0.02	0.02	0.02	0.80	0.70	0.90	750424	750428
173	175	178	0.02	0.02	0.02	0.90	0.80	0.80	750428	750501
172	205	206	0.02	0.02	0.02	0.80	0.50	0.50	750501	750505
199	202	203	0.02	0.03	0.05	0.50	0.56	0.55	750505	750508
174	182	182	0.04	0.03	0.02	0.40	0.36	0.40	750508	750512
180	179	178	0.02	0.02	0.02	0.30	0.30	0.35	750512	750515
175	201	203	0.02	0.02	0.02	0.30	0.30	0.35	750515	750519
215	207	205	0.01	0.02	0.02	0.20	0.46	0.40	750519	750522
207	203	205	0.02	0.02	0.02	0.40	0.30	0.25	750522	750527
210	232	[illegible]	0.02	0.05	0.04	0.30	0.40	0.40	750527	750529
247	236	[illegible]	0.03	0.02	0.02	0.40	0.60	0.60	750529	750602
236	224	226	0.02	0.02	0.02	0.70	0.70	0.80	750602	750604
215	222	225	0.02	0.02	0.02	0.80	0.70	0.80	750604	750606
214	179	183	0.02	0.02	0.02	0.70	0.74	0.70	750606	750609
165	168	162	0.02	0.02	0.02	0.90	1.00	0.85	750609	750611
167	167	160	0.02	0.03	0.02	1.00	0.40	0.45	750611	750616
174	168	160	0.03	0.03	0.02	0.50	0.50	0.55	750616	750618
156	157	159	0.02	0.02	0.02	0.60	0.54	0.50	750619	750620
156	151	156	0.02	0.04	0.04	0.60	0.56	0.55	750620	750623
152	138	158	0.05	0.02	0.02	0.50	0.60	0.60	750623	750625
151	170	160	0.02	0.02	0.02	0.50	0.61	0.80	750625	750627
191	173	179	0.02	0.02	0.02	0.70	0.70	0.65	750627	750630
185	193	193	0.02	0.02	0.02	0.70	0.70	0.70	750630	750702
208	246	247	0.04	0.04	0.04	0.80	0.60	0.60	750702	750707

CONTINUED

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

DISSOLVED SOLIDS LD=1MG/L			AMMONIA AS N LD=0.02MG/L			NITRATE AS N LD=0.01MG/L			SAMPLE DATE OF I	SAMPLE DATE OF B&C
I	B	C	I	B	C	I	B	C	Y M D	Y M D
280	265	262	0.02	0.07	0.07	0.60	0.60	0.65	750707	750709
300	272	273	0.15	0.06	0.06	0.60	0.60	0.55	750709	750711
288	268	265	0.10	0.02	0.02	0.50	0.60	0.50	750711	750714
288	272	270	0.02	0.05	0.03	0.60	0.53	0.50	750714	750716
280	293	290	0.05	0.07	0.05	0.60	0.50	0.50	750716	750718
316	321	322	0.02	0.13	0.12	0.50	0.50	0.40	750718	750721
325	330	332	0.22	0.13	0.12	0.15	0.36	0.40	750721	750723
340	316	318	0.21	0.18	0.21	0.20	0.36	0.35	750723	750725
318	318	315	0.20	0.11	0.12	0.10	0.36	0.35	750725	750728
302	328	333	0.11	0.10	0.10	0.20	0.30	0.35	750728	750730
327	306	317	0.13	0.09	0.09	0.20	0.36	0.30	750730	750801
312	305	315	0.10	0.08	0.09	0.20	0.50	0.60	750801	750804
312	312	326	0.09	0.12	0.13	0.50	0.70	0.70	750804	750806
341	326	329	0.09	0.11	0.13	0.80	0.90	0.90	750806	750808
351	319	319	0.13	0.15	0.15	1.10	0.90	0.90	750808	750811
288	326	316	0.13	0.08	0.08	0.90	0.90	0.80	750811	750813
312	311	307	0.09	0.10	0.11	0.90	0.65	0.65	750813	750815
326	321	326	0.10	0.02	0.05	0.70	0.60	0.55	750815	750818
326	328	328	0.02	0.05	0.03	0.80	0.75	0.70	750818	750820
322	335	337	0.05	0.05	0.05	0.90	1.00	1.00	750820	750822
330	326	326	0.04	0.02	0.02	1.10	1.10	1.10	750822	750825
312	313	311	0.02	0.02	0.02	1.25	1.00	1.10	750825	750827
300	311	300	0.02	0.02	0.02	1.10	1.05	1.00	750827	750829
300	279	279	0.02	0.02	0.02	1.10	0.60	0.65	750829	750903
256	261	263	0.02	0.02	0.02	0.60	0.56	0.65	750903	750905
265	252	247	0.02	0.02	0.02	0.60	0.60	0.65	750905	750908
220	226	230	0.02	0.02	0.02	0.60	0.80	0.80	750908	750910
213	228	229	0.02	0.02	0.02	0.70	0.80	0.80	750910	750912
223	218	218	0.02	0.02	0.02	0.80	0.70	0.70	750912	750915
217	229	232	0.02	0.02	0.02	0.70	0.76	0.70	750915	750917
227	236	238	0.02	0.02	0.02	0.50	0.76	0.75	750917	750919
226	206	207	0.02	0.02	0.02	0.70	0.76	0.65	750919	750922
193	208	211	0.02	0.02	0.02	0.60	0.65	0.65	750922	750924
195	203	205	0.02	0.02	0.02	0.50	0.70	0.65	750924	750926
200	201	202	0.02	0.02	0.02	0.70	0.66	0.65	750926	750929
201	207	211	0.02	0.02	0.02	0.70	0.80	0.75	750929	751001
195	199	217	0.02	0.02	0.02	0.50	0.66	0.70	751001	751003
178	179	176	0.02	0.02	0.02	0.60	0.50	0.55	751003	751007
186	183	179	0.02	0.02	0.02	0.40	0.80	0.75	751007	751009
197	198	199	0.02	0.02	0.02	0.70	0.80	0.70	751009	751014
203	215	219	0.02	0.02	0.02	0.80	0.90	0.90	751014	751016
216	189	188	0.02	0.02	0.02	0.90	0.76	0.80	751016	751021
177	179	179	0.02	0.02	0.02	0.70	0.80	0.80	751021	751023
189	184	189	0.02	0.02	0.02	0.80	0.80	0.90	751023	751028
175	195	187	0.02	0.02	0.02	0.90	0.90	0.80	751028	751030
178	170	167	0.02	0.02	0.02	0.90	0.90	0.60	751030	751106
186	197	198	0.02	0.02	0.02	0.50	0.56	0.55	751106	751113
205	172	172	0.02	0.02	0.02	0.50	0.60	0.55	751113	751118

CONTINUED

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

DISSOLVED SOLIDS LD=1MG/L			AMMONIA AS N LD=0.02MG/L			NITRATE AS N LD=0.01MG/L			SAMPLE DATE OF I	SAMPLE DATE OF E&C
I	E	C	I	E	C	I	E	C	Y M D	Y M D
167	170	173	0.02	0.02	0.02	0.60	0.50	0.50	751118	751120
168	180	189	0.02	0.02	0.02	0.50	0.70	0.75	751120	751125
195	170	173	0.02	0.02	0.02	0.60	0.60	0.60	751125	751202
171	165	165	0.02	0.02	0.02	0.60	0.56	0.60	751202	751204
161	195	195	0.02	0.02	0.02	0.50	0.74	0.70	751204	751209
180	190	194	0.02	0.02	0.02	0.80	0.70	0.70	751209	751211
179	157	148	0.02	0.02	0.02	0.70	0.70	0.70	751211	751216
151	150	151	0.02	0.02	0.02	0.70	0.70	0.70	751216	751218
149	135	126	0.02	0.02	0.02	0.70	0.90	0.90	751218	751223
121	199	194	0.02	0.02	0.02	0.90	0.66	0.70	751223	751230
167	78	135	0.02	0.01	0.02	0.60	0.34	0.70	751230	760106
134	171	169	0.02	0.02	0.02	0.60	0.90	0.90	760106	760113
185	91	267	0.02	0.01	0.02	0.80	0.45	0.80	760113	760115
193	96	117	0.02	0.01	0.02	0.80	0.96	1.00	760115	760120
171	193	197	0.02	0.02	0.02	1.00	0.95	0.90	760120	760127
200	197	194	0.02	0.02	0.02	0.90	0.84	0.85	760127	760129

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TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

TOTAL PHOSPHATE AS PO4 (LD=0.01MG/L)			SOLUBLE ORTHO PHOSPHATE AS PO4 (LD=0.01MG/L)			TOTAL ORTHO PHOSPHATE AS PO4 (LD=0.01MG/L)			SAMPLE DATE OF T	SAMPLE DATE OF B&C
T	B	C	T	B	C	T	B	C	Y M D	Y M D
0.18	0.12	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750203	750206
0.26	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750206	750210
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750210	750213
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750213	750218
0.01	0.10	0.10	0.01	0.01	0.01	0.01	0.01	0.01	750218	750220
0.10	0.01	0.10	0.01	0.01	0.11	0.01	0.01	0.01	750220	750224
0.10	0.01	0.01	0.10	0.01	0.01	0.01	0.01	0.01	750224	750227
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750227	750303
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750303	750306
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750306	750310
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750310	750313
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750313	750317
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750317	750320
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750320	750324
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750324	750327
0.01	0.10	0.36	0.01	0.01	0.01	0.01	0.01	0.01	750327	750331
0.15	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750331	750403
0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750403	750407
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750407	750410
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750410	750414
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750414	750417
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750417	750421
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750421	750424
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750424	750428
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750428	750501
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750501	750505
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750505	750508
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750508	750512
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750512	750515
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750515	750519
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750519	750522
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750522	750527
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750527	750529
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750529	750602
0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750602	750604
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750604	750606
0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750606	750609
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750609	750611
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750611	750616
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750616	750618
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750618	750620
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750620	750623
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750623	750625
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750625	750627
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750627	750630
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750630	750702

Continued

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

TOTAL PHOS-PHATE AS PO4 LOD=0.01MG/L			SOLUBLE ORTHO PHOSPHATE AS PO4 LOD=0.01MG/L			TOTAL ORTHO PHOSPHATE AS PO4 LOD=0.01MG/L			SAMPLE DATE OF I	SAMPLE DATE OF END
I	B	E	I	B	E	I	B	E	Y M D	Y M D
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750702	750707
0.10	0.35	0.06	0.01	0.01	0.01	0.01	0.01	0.01	750707	750709
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750709	750711
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750711	750714
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750714	750716
0.01	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750716	750718
0.01	0.13	0.20	0.01	0.01	0.01	0.01	0.01	0.01	750718	750721
0.08	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750721	750723
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750723	750725
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750725	750728
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750728	750730
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750730	750801
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.13	0.08	750801	750804
0.20	0.12	0.15	0.01	0.10	0.01	0.23	0.13	0.01	750804	750806
0.19	0.05	0.01	0.15	0.01	0.01	0.17	0.01	0.01	750806	750808
0.01	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750808	750811
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750811	750813
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750813	750815
0.01	0.01	0.01	0.01	0.01	0.01	0.11	0.01	0.01	750815	750818
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750818	750820
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750820	750822
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750822	750825
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750825	750827
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750827	750829
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750829	750903
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750903	750905
0.01	0.01	0.01	0.01	0.01	0.11	0.01	0.01	0.01	750905	750908
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750908	750910
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750910	750912
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750912	750915
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750915	750917
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750917	750919
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750919	750922
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750922	750924
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750924	750926
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750926	750929
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	750929	751001
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751001	751003
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751003	751007
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751007	751009
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751009	751014
0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751014	751016
0.20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751016	751021
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751021	751023
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751023	751028
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751028	751030
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751030	751104

CONTINUED

TABLE A-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

TOTAL PHOSPHATE AS PO4 LE=0.01MG/L			SOLUBLE ORTHO PHOSPHATE AS PO4 LE=0.01MG/L			TOTAL ORTHO PHOSPHATE AS PO4 LE=0.01MG/L			SAMPLE DATE OF T	SAMPLE DATE OF M/B
T	M	B	T	M	B	T	M	B	Y M D	Y M D
0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751106	751113
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751113	751118
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751118	751120
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751120	751125
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751125	751202
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751202	751204
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751204	751209
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751209	751211
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751211	751216
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751216	751218
0.01	0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751218	751223
0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751223	751230
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	751230	760106
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	760106	760113
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	760113	760115
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	760115	760120
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	760120	760127
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	760127	760129

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

LEAD LT=0.001MG/L I	LEAD LT=0.001MG/L E	LEAD LT=0.001MG/L L	COPPER LT=0.001MG/L I	COPPER LT=0.001MG/L E	COPPER LT=0.001MG/L L	SAMPLE DATE OF I Y M D	SAMPLE DATE OF E&L Y M D
0.001	0.001	0.001	0.010	0.010	0.010	750203	750206
0.001	0.001	0.001	0.010	0.010	0.010	750206	750210
0.001	0.001	0.001	0.010	0.008	0.010	750210	750213
0.001	0.001	0.001	0.010	0.010	0.010	750213	750218
0.001	0.001	0.001	0.010	0.010	0.010	750218	750220
0.001	0.001	0.001	0.010	0.010	0.010	750220	750224
0.001	0.001	0.001	0.010	0.010	0.010	750224	750227
0.001	0.001	0.001	0.010	0.010	0.010	750227	750303
0.001	0.001	0.001	0.010	0.010	0.010	750303	750306
0.001	0.001	0.001	0.010	0.010	0.010	750306	750310
0.001	0.001	0.001	0.010	0.010	0.010	750310	750313
0.001	0.001	0.001	0.010	0.010	0.010	750313	750317
0.001	0.001	0.001	0.010	0.010	0.010	750317	750320
0.001	0.001	0.001	0.010	0.010	0.010	750320	750324
0.001	0.001	0.001	0.010	0.010	0.010	750324	750327
0.001	0.001	0.001	0.010	0.010	0.010	750327	750331
0.001	0.038	0.011	0.010	0.010	0.010	750331	750403
0.016	0.011	0.009	0.010	0.010	0.010	750403	750407
0.014	0.036	0.037	0.010	0.010	0.010	750407	750410
0.005	0.001	0.001	0.010	0.010	0.010	750410	750414
0.004	0.042	0.013	0.010	0.010	0.010	750414	750417
0.030	0.017	0.020	0.010	0.010	0.010	750417	750421
0.030	0.020	0.026	0.010	0.010	0.010	750421	750424
0.020	0.005	0.001	0.010	0.010	0.010	750424	750428
0.010	0.037	0.039	0.010	0.010	0.010	750428	750501
0.020	0.020	0.020	0.010	0.010	0.010	750501	750505
0.018	0.018	0.017	0.010	0.010	0.010	750505	750508
0.010	0.013	0.017	0.010	0.010	0.010	750508	750512
0.012	0.028	0.039	0.010	0.010	0.010	750512	750515
0.020	0.015	0.013	0.010	0.010	0.010	750515	750519
0.025	0.028	0.027	0.010	0.010	0.010	750519	750522
0.020	0.021	0.026	0.010	0.010	0.010	750522	750527
0.018	0.027	0.025	0.010	0.010	0.010	750527	750529
0.020	0.036	0.017	0.010	0.010	0.010	750529	750602
0.006	0.023	0.036	0.010	0.010	0.010	750602	750605
0.017	0.043	0.021	0.010	0.010	0.010	750605	750606
0.010	0.008	0.008	0.010	0.010	0.010	750606	750609
0.038	0.019	0.019	0.010	0.010	0.010	750609	750611
0.013	0.023	0.021	0.010	0.010	0.010	750611	750616
0.030	0.020	0.021	0.010	0.010	0.010	750616	750618
0.020	0.020	0.021	0.010	0.010	0.010	750618	750620
0.014	0.001	0.011	0.010	0.010	0.010	750620	750623
0.015	0.011	0.008	0.010	0.010	0.010	750623	750625
0.007	0.003	0.008	0.010	0.010	0.010	750625	750627
0.009	0.036	0.037	0.010	0.010	0.010	750627	750630
0.026	0.029	0.013	0.010	0.010	0.010	750630	750702
0.013	0.015	0.017	0.010	0.010	0.010	750702	750707

CONTINUED

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

LEAD LD=0.001MG/L 1	2	3	COPPER LD=0.001MG/L 1	2	3	SAMPLE DATE OF 1 Y M D	SAMPLE DATE OF 2&3 Y M D
0.020	0.022	0.015	0.020	0.010	0.013	750707	750709
0.012	0.010	0.011	0.010	0.010	0.013	750709	750711
0.010	0.009	0.013	0.010	0.010	0.013	750711	750714
0.006	0.011	0.018	0.010	0.010	0.010	750714	750716
0.026	0.018	0.019	0.010	0.010	0.013	750716	750718
0.010	0.018	0.022	0.010	0.010	0.013	750718	750721
0.038	0.011	0.019	0.010	0.010	0.013	750721	750723
0.010	0.015	0.017	0.010	0.010	0.013	750723	750725
0.010	0.021	0.023	0.010	0.010	0.013	750725	750728
0.015	0.025	0.030	0.010	0.010	0.013	750728	750730
0.018	0.019	0.011	0.010	0.010	0.013	750730	750801
[illegible]	0.012	0.012	0.010	0.100	0.013	750801	750804
0.011	0.014	0.016	0.200	0.100	0.013	750804	750806
0.016	0.021	0.022	0.190	0.010	0.010	750806	750808
0.019	0.001	0.001	0.010	0.010	0.013	750808	750811
0.032	0.001	0.001	0.010	0.010	0.013	750811	750813
	0.001	0.001	0.010	0.010	0.013	750813	750815
	0.014	0.016	0.010	0.010	0.013	750815	750818
0.036	0.017	0.019	0.010	0.010	0.013	750818	750820
0.005	0.014	0.016	0.010	0.010	0.013	750820	750822
0.012	0.024	0.180	0.010	0.010	0.013	750822	750825
0.020	0.019	0.010	0.010	0.010	0.013	750825	750827
0.019	0.001	0.001	0.010	0.010	0.013	750827	750829
	0.025	0.025	0.010	0.010	0.013	750829	750903
0.040	0.022	0.017	0.010	0.010	0.010	750903	750905
0.010	0.019	0.019	0.010	0.010	0.013	750905	750908
0.010	0.022	0.021	0.010	0.010	[illegible]	750908	750910
0.022	0.020	0.027	0.010	0.010	0.013	750910	750912
0.026	0.011	0.020	0.010	0.010	0.013	750912	750915
0.035	0.013	0.016	0.010	0.010	0.010	750915	750917
0.006	0.010	0.013	0.010	0.010	0.013	750917	750919
0.006	0.009	0.017	0.010	0.010	0.013	750919	750922
0.005	0.006	0.015	0.010	0.010	0.013	750922	750924
0.034	0.010	0.019	0.010	0.010	0.013	750924	750926
0.007	0.017	0.020	0.010	0.010	0.010	750926	750929
0.011	0.009	0.019	0.010	0.010	0.013	750929	751001
0.033	0.016	0.021	0.010	0.010	0.013	751001	751003
0.013	0.018	0.027	0.010	0.010	0.013	751003	751007
0.019	0.036	0.036	0.010	0.010	0.013	751007	751009
0.005	0.017	0.019	0.010	0.010	0.010	751009	751014
0.005	0.007	0.008	0.010	0.010	0.010	751014	751016
0.008	0.035	0.006	0.010	0.010	0.013	751016	751021
0.023	0.031	0.012	0.010	0.010	0.013	751021	751023
0.010	0.022	0.025	0.010	0.010	0.013	751023	751028
0.010	0.017	0.020	0.010	0.010	0.013	751028	751030
0.030	0.015	0.018	0.010	0.010	0.013	751030	751106
0.019	0.016	0.016	0.010	0.010	0.013	751106	751113
0.037	0.026	0.031	0.010	0.010	0.013	751113	751118

CONTINUED

TABLE B-1 (CONTINUED)

WATER QUALITY SAMPLING DATA FOR HIGHLAND RESERVOIR NO. 1

LEAD LD<0.001MG/L I	LEAD E	LEAD L	COPPER LD<0.001MG/L I	COPPER E	COPPER L	SAMPLE DATE OF I Y M D	SAMPLE DATE OF E&L Y M D
0.020	0.022	0.025	0.010	0.010	0.010	751118	751120
0.022	0.032	0.021	0.010	0.010	0.010	751123	751125
0.030			0.010	0.010	0.011	751125	751202
			0.010	0.010	0.01[illegible]	751202	751205
	0.013	0.011	0.010	0.010	0.010	751206	751209
0.028	0.011	0.015	0.010	0.010	0.010	751209	751211
0.013	0.007	0.005	0.010	0.010	0.010	751211	751216
0.026	0.013	0.016	0.010	0.010	0.010	751216	751219
0.013			0.010	0.010	0.010	751218	751223
	0.038	0.010	0.010	0.010	0.010	751223	751230
0.036	0.005	0.010	0.010	0.006	0.010	751230	760106
0.005	0.006	0.005	0.010	0.010	0.010	760106	760113
0.001	0.006	0.010	0.010	0.006	0.010	760113	760115
0.030	0.005	0.008	0.010	0.006	0.010	760115	760120
0.025	0.036	0.006	0.010	0.010	0.010	760120	760127
0.035	0.008	0.010	0.010	0.010	0.010	760127	760129